Defense Science Board
1996 Summer Study Task Force
on
Tactics and Technology for 21st Century Military Superiority

Volume 1
Final Report

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

October 1996

#833

Office of the Secretary of Defense
Washington D.C. 20301-3140

OFFICE OF THE SECRETARY OF DEFENSE
3140 DEFENSE PENTAGON
WASHINGTON, DC 20301-3140

DEFENSE SCIENCE BOARD

MEMORANDUM FOR UNDER SECRETARY OF DEFENSE (ACQUISITION & TECHNOLOGY)
CHAIRMAN OF THE JOINT CHIEFS OF STAFF

SUBJECT: Report of the Defense Science Board (DSB) Task Force on Tactics and Technology for 21st Century Military Superiority.

I am forwarding the final report of the 1996 Defense Science Board Summer Study of Tactics and Technology for 21st Century Military Superiority. The Task Force report identifies ways to achieve substantial increases in the effectiveness of rapidly deployable forces and fulfills your charge to the DSB to take a more comprehensive look at concepts briefly sketched in last year's DSB Summer Study on Technology for 21st Century Military Superiority. We see strong motivation for doing so. Without such enhancements the U.S. will likely face 21st century security challenges with a military force that is perceived as either too vulnerable or too late.

The essence of the concept described within this report is an unprecedented reliance on "remote" elements — sensors, processors, weapons — coupled to a ground component organized around light agile combat cells, all interconnected by a robust information infrastructure. This highly distributed and potent expeditionary force could take on a variety of 21st century missions, either on its own or as preparatory to the arrival of follow-on forces. The Task Force concludes that such a force is feasible and the concept can be refined, tested and evolved into fielded capabilities over the next 20 years. It builds on a variety of rapidly progressing technologies — low cost precision fire, sensors, information processing — to enable new concepts of operations and tactics.

The Task Force offers several recommendations on how the Department should bring such a capability into being. The most important recommendation is to establish a dedicated joint effort, under an Executive Agent, to explore and evolve the concept. This effort would involve extensive simulations, red teaming and field experiments and eventually encompass a variety of existing and new advanced concept technology demonstrations (ACTDs).

A potentially contentious issue is how to manage and organize this joint effort. As alluded to in the report, there is no ideal place within today's DoD for something both as novel and intrinsically joint as this distributed expeditionary force concept. Any proposed approach will have some shortcomings and detractors. The Task Force offers its view of the preferred arrangement. Other approaches could also work given firm commitment and support from the top.

I enthusiastically support the findings and recommendations of this Task Force and advise that you together initiate the joint effort that is necessary to explore and evolve this concept.

Craig I. Fields
Chairman

DEFENSE SCIENCE BOARD

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MEMORANDUM FOR THE CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Report of the Defense Science Board (DSB) Task Force on Tactics and Technology for 21st Century Military Superiority.

Attached is the final report of the 1996 Defense Science Board Summer Study Task Force on Tactics and Technology for 21st Century Military Superiority. Our Task Force was charged to explore new ways to make rapidly deployable forces much more effective than they are today. Based on our work, we believe that substantial, possibly revolutionary, improvements in the effectiveness of rapidly deployable forces are feasible. The concepts described in the report can be refined, tested and evolved into fielded capabilities over the next two decades. Furthermore, these concepts have broad applicability beyond the time urgent conditions of rapid deployment.

The essence of this new expeditionary force concept is an ability to mass fire rather than forces. It relies on an ensemble of remote weapons effective against all types of targets; an extensive suite of sensors, information processors and information warfare capabilities to provide situation understanding dominance; a ground force comprised of light agile combat cells that offers few targets for the enemy; a precision logistics capacity that provides the right stuff at the right place at the right time; and a robust information infrastructure that ties this distributed force together.

The report describes potential ways to achieve these capabilities as well as meet other challenges including command, force insertion and training. The report also describes how this new force concept could operate to perform various missions in different environments. In addition to this summary volume, we have produced two supporting volumes which include reports from the Task Force Panels, analyses done for the Task Force by others and a collection of papers on potential technology applications. While we don't expect that we got most of the details right, this work should provide a rich starting point for further development and experimentation.

It is not surprising, given that the concept is new, broadly applicable and comprised of widely disparate elements, that portrayals of it differ, even among members of our DSB Task Force. Many of the Task Force participants view the ground force as central to the concept with the remote sensors, processors and weapons the supporting cast. However, it is equally plausible to consider the remote elements as the core. Our own view emphasizes the distributed nature of the force both with respect to the interdependency of the ground force and the remote suites of sensors, weapons and other systems as well as to the greatly dispersed posture of the ground force itself.

The report offers several recommendations. By far the most important is to establish a joint effort, under the leadership of an executive agent, to explore and exploit the concept. There is no ideal home within DoD for the exploration of something both as new and as

intrinsically joint as this distributed expeditionary force. While a CINC leadership would bring the joint perspective, the Services are better positioned today to start running with this concept.

This effort will require analysis, simulation, red teaming and field experiments to expose and overcome vulnerabilities and to determine how best to integrate and evolve new tactics, CONOPS, technology and training into revolutionary new warfighting capabilities. We also recommend that a new operational task force be established to be the initial customer for the capabilities that evolve out of this effort.

We estimate the cost of the joint effort to explore the concept to be several hundred million dollars per year. If the concept proves robust, then it eventually could have a major influence on resource allocation.

There are technology programs underway addressing some of the capabilities necessary to implement this concept. We identify other areas where more effort will be needed: loitering weapons (including armed UAVs), sea-based fire support (surveillance, targeting and C^3, as well as missiles and guns), lower cost precision munitions, sensor and information management (to provide a Cooperative Engagement Capability-like picture of the ground war), robotics, low observable ground vehicles, insertion air platforms, and the means to tie the ground combatants to the information infrastructure.

We also have recommendations for implementing a robust information infrastructure without which this distributed force concept is impossible. A necessary step is to designate an enforcer of compliance to the "building codes" established by a joint technical information architecture. This will facilitate the use of commercial technology and products necessary to put together an affordable and open systems architecture which in turn can provide the desired functions of the operational architecture.

Several necessary conditions for the sort of revolutionary new capabilities we envision are already in place. First, there is a compelling strategic rationale — without substantial enhancements the U.S. may face 21st century contingencies with a military force that will be perceived as either too slow arriving or too vulnerable. Second, there is high expectation that enabling technologies will be available during the next two decades to support new operational concepts and tactics. Lastly there are efforts already underway within the Services to explore such new warfighting concepts, thus there is fertile soil in which to plant the ideas.

Commensurate with the nature of our task, the Summer Study Group was unusually large with particularly strong military participation (retired and active). The exceptional commitment of time and energy from the participants reflects, we are convinced, their belief in the importance of our task and the feasibility of new approaches. We thank all the members and government advisors of this Task Force for their dedication, enthusiasm, hard work, and certainly not least, their diligence in providing written material.

Theodore S Gold

Theodore S Gold
Co-Chairman

Donald C. Latham

Donald C. Latham
Co-Chairman

SUMMARY

Unless the U.S. is able to enhance the effectiveness of the military forces that it can very rapidly bring to bear in overseas crises it will have diminishing ability to influence events and protect its interests and commitments in the 21st century.

The reasons are spelled out in the 1995 DSB Summer Study which posited 21st century regional adversaries with the motives to accomplish their military goals quickly and the means to disrupt and delay U.S. Desert Shield-type military deployments to their neighborhood. Rapid and effective application of U.S. military force can prevent bad situations from becoming much worse and a demonstrated capability may help dissuade aggression in the first place. This 1996 DSB Summer Study on Tactics and Technology for 21st Century Military Superiority was tasked to identify how to make rapidly deployable forces more potent.

Based on its analysis, this Task Force believes that substantial, possibly revolutionary, enhancements of the effectiveness of rapidly deployable military forces are feasible. We believe that the concepts we explored in this study can be refined, tested, modified, shaped and evolved into fielded capabilities over the next 10-20 years. The Task Force believes that the technology can be brought to necessary maturity to enable new CONOPS and tactics during this time within reasonable resource expenditures.

Air- and sea-based firepower alone may well be sufficient to deal with certain military challenges confronting the U.S. in the 21st century. However, for both military and geopolitical reasons, many potential future military contingencies will offer critical early roles for U.S. ground forces in theater. These roles include integrating with coalition forces, complementing remote sensors by filling in gaps and resolving ambiguities, identifying noncombatants, securing points of debarkation for follow-on forces, temporarily controlling territory, locating and neutralizing weapons of mass destruction (WMD) capabilities, and preparing to make more permanent the gains achieved by long range precision strike. Thus, the conceptual approach outlined in this report provides for the rapid insertion of ground forces as well as for air- and sea-based firepower.

This expeditionary force concept will not deal with all future military contingencies. It would serve as a precursor force to help deter aggression, halt attacks, secure critical areas and in general prepare the way for the later arrival of more extensive forces. It could accomplish other missions, particularly those on the lower end of the conflict scale, on its own: getting in, doing the job and getting out quickly. It clearly is not intended for major offensive ground campaigns although the sort of rapidly deployable military capability we envision would contribute to avoiding the need to conduct such campaigns. The concept borrows features associated with Special Operations Forces (SOF) but its operations would in general be of a larger scale that the SOF's and be overt rather than covert.

The Task Force's concept exploits the enormous and barely scratched potential of emerging capabilities to provide theater wide situation understanding, effective remote fires and a robust interconnected information infrastructure. We use the

term "situation understanding" throughout this report to represent the higher order knowledge obtained when situation awareness is combined with appropriate context and training.

We envision the integration of these capabilities with a ground force redesigned from the bottom up, starting with the "combat cell," the smallest warfighting unit. The resultant ground force would be comprised of 10-20+ man light, agile combat cells and, depending on the operational environment, a heliborne armed reconnaissance capability. Such combat cells would operate in highly dispersed postures, presenting few concentrated targets for the enemy. The combat cells could also coalesce into larger units when necessary. Initial analysis suggests that equipping the cells with organic vehicles significantly enhances their effectiveness and survivability. Stealth, situation understanding and information warfare will be vital ingredients in their survival kit. The concepts also call for extensive use of unmanned vehicles and robotics, and rely on a substantially reduced logistical footprint.

The Task Force believes considerably more attention to these ground combat cells is warranted. Light infantry, getting relatively little notice and resources from the Pentagon, has not changed much in capability over many decades but has great potential for enhancement if enabled by new tactics and technology.

A joint and distributed expeditionary task force — comprised of light and agile ground and air combat cells coupled to remote suites of sensors, weapons and information processors — can be a potent military force, able to take on missions (at least for limited duration) now requiring much larger and heavier forces on the ground:

- **New levels of situation understanding are necessary to enable effective remote fires and ground operations in widely dispersed postures.** It can be provided by sensor and information management suites able to do for the ground war what the Cooperative Engagement Capability (CEC), is beginning to do for the fleet air defense. The goal is to provide a comprehensive, shared, fire control (and combat identification) quality picture of the ground environment. The picture is derived by fusing the data (high resolution, multispectral, geometrically diverse) from multiple sensors on a variety of platforms from satellites, aircraft and unmanned aerial vehicles (UAVs) to unattended ground sensors and micro air vehicles. Management of this diverse sensor suite and the information it produces will become a critical task for future theater and battlefield commanders. Traditional distinctions between intelligence and tactical surveillance will disappear.

- **This new expeditionary force will be dependent on remote fires that are effective against a variety of targets.** It will not be sufficient to merely rebase historical weights and rates of fire. The fire must be made much more efficient and the demand for emergency fire must be reduced. The keys to accomplishing these are affordable precision weapons and greatly enhanced situation understanding which will turn today's fleeting observations into tomorrow's tracked targets. With the appropriate ensemble of weapons, this will permit us to attack the enemy when he is most valuable and most vulnerable. Shortening the time of flight of the remote

weapons will not, by itself, provide the requisite responsiveness and, thus, there will be important roles for loitering weapons and in-flight updates to incoming weapons. The remote fires could be delivered by land-based tactical aircraft if the bases are available and more generally by bombers and sea-based aircraft, missiles and long range guns. We envision an important role for armed UAVs as well.

- **A necessary foundation for this concept is a robust information infrastructure.** It must not only provide secure communication among the distributed participants but also geographical location, precise time, telemedicine and other functions. The multitiered communication network makes use of geosynchronous and low earth orbit satellites, aircraft and UAVs. The ground combatants' portal into this infrastructure will be a personal information ensemble based on commercial cellular technologies, able to provide paging, conferencing and even imaging services. Intelligent software agents will help manage both the operation of the network and the applications of the information that flows through it.

- **The robust wide band communication networks and enhanced situation understanding offer the potential for both more centralized control (the CINC can see "everything") and more decentralized empowerment (the combat cell commander can see what the CINC sees).** These capabilities can present future commanders both opportunities to exploit and tensions to resolve. A major challenge will be the exploration of the command relationships that best take advantage of these additional degrees of freedom. We will not be able to eliminate the fog of war. We can, however, provide the tools and training to help the combatants, from Joint Task Force commander to combat cell member, better deal with the uncertainty and chaos that will remain intrinsic to combat.

The Task Force explored and analyzed the concept in several environments — halting combined arms attacks, controlling territory in the presence of hostile militia and conducting operations in urban terrain. The results are discussed in the report and more detail is provided in Volume 2. While we do not expect that we got all or even most of the details right, they provide a starting point for further development and experimentation. The report also provides more detail on the systems and associated concepts of operation needed to provide the situation understanding, remote fires, information infrastructure and force insertion, extraction, sustainment and survivability. The substantial implications for training these expeditionary and dispersed force concepts are also discussed.

Several necessary conditions for the sort of revolutionary changes we envisage are already in place:

- **There is a compelling strategic rationale,**
- **The enabling technologies are maturing rapidly and,**
- **There are efforts now underway within the Services to explore such new warfighting concepts.**

What is missing are the organizations and processes necessary to test and evolve joint warfighting architectures for new concepts such as the distributed, expeditionary force concept proposed here: agile ground combat cells, coupled to

ensembles of distributed remote sensors and precision weapons, all interconnected by a robust information infrastructure and supported by smart logistics techniques.

The Task Force offers three sets of recommendations. The most important is to establish a joint effort and a "try before buy" environment to pursue these concepts. The joint effort, sponsored by the Secretary of Defense and the Chairman, JCS, would develop, test, analyze, and evolve these concepts through a series of experiments (to learn, not prove), supported by refocused simulation and analysis capabilities. Our adversaries will surely work hard and creatively to expose potential vulnerabilities in the distributed force concept. Furthermore, they will have access to much of the same technology that enables the concept. Their countermeasures will call for counter-countermeasures. Some of their responses may limit the applicability of the concept, others could prove to be more damaging to its basic viability. An energetic Red Team must be an integral part of the process to explore and develop these new warfighting concepts.

The second set of recommendations calls for support of critical enabling systems and mechanisms — many already ongoing, others new. These include making the USD(A&T) and the ASD (C^3I) the enforcers of the joint technical information architecture and providing funds to equip some of our light infantry forces with modern communication, navigation and targeting technology. The third set of recommendations calls for the establishment by 1998 of a joint operational task force to be the primary recipient of the products — tactics and technology — that evolve from the above efforts.

At the very least, pursuit of these concepts will yield potent multipliers for "standard" forces and tactics. There is a good chance that we can achieve dramatic increases in the effectiveness of rapidly deployable forces if redesigning the ground forces around the enhanced combat cell proves to be robust in many environments. There is some chance that all this will amount to a true revolution in military affairs by "eliminating the reliance of our forces on the logistics head as Blitzkrieg freed the offense after World War I from its then decades old reliance on the railhead." *

* From a presentation to the DSB Task Force by MG Robert H. Scales, USA, entitled "Modern Land Warfare Follows Technology Driven Cycles."

Section I
Introduction

"Information is the soul of morale in combat."

S.L.A. Marshall

Colonel, USA (RET)

Table of Contents

Volume 2 - Supporting Materials

Part 2 (Classified) (Under Separate Cover)

Table of Contents

Volume 1 - Final Report

Volume 2 - Supporting Materials

Part 1 (Unclassified) (Under Separate Cover)

Forward

This report of the Defense Science Board Summer Study on Tactics and Technology for 21st Century Military Superiority includes three volumes. Volume 1 provides a summary of the principal findings and recommendations of this Task Force. This volume represents the consensus view of the Task Force along with supporting analytical results.

Volume 2 contains a set of supporting materials prepared by Task Force panels, or provided as inputs to this Task Force. Each section of Volume 2 is shown with its author(s).

Volume 3 is a collection of papers on relevant technologies. Some papers were prepared by Task Force members. Most were contributed by other experts in response to requests by the DSB Task Force. The author(s) for each paper is shown.

III. PRECISION WEAPONS

IV. FORCE ENHANCEMENT

V. LOCAL AREA SURVEILLANCE / WEAPONS

VI. URBAN OPERATIONS

VII. INDIVIDUAL SYSTEMS

THE TASK FORCE FOCUS FROM THE TERM OF REFERENCE

The Task Force should focus on the concept of employing relatively small and rapidly deployable forces specially equipped, trained, and supported by remote sensors and weapons -- capable of executing missions hereto for only possible with much larger and massed forces.

The Terms of Reference (abstracted in the figure and provided in Appendix A) pose three basic questions:

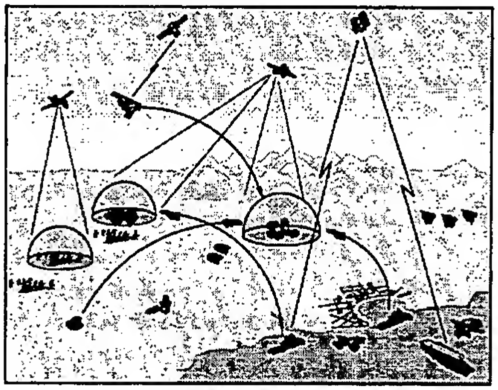
- What are the realistic missions and how does the concept fit within larger military strategies and force employment?
- What operational and technical capabilities are needed?
- How and when can DoD turn the concept into an operational capability?

Our potential adversaries will also not be standing still. The DSB Summer Study of 1995 posited regional adversaries that were very formidable, even at modest budget levels, by use of widely available 21st century technologies in selective and innovative applications to undercut current U.S. plans, programs, and combat concepts. Thus we also consider potential countermeasures to the concept.

The time horizon for this study is the next twenty years, with our attention focused beyond the current POM and its associated forces. This is sufficiently long to allow for profound change, while near enough to have to begin taking actions now to affect these changes. The opportunity for profound change over this time period can be appreciated by noting the remarkable advances that have occurred during the past twenty years in precision weaponry, stealth, and particularly, in information technology.

The goal is an eventual revolutionary increase in the capabilities of rapidly deployable forces, achieved over the next few decades through an evolutionary insertion of new tactics and technology.

ESSENCE OF THE CONCEPT



A rapidly deployable force
- Light
- Agile
- Potent

The force is
- Distributed and disaggregated
- Empowered by unprecedented situation understanding
- Dependent on remote fires
- Connected by robust information infrastructure
- Supported by precision logistics

The basic elements of the concept that we explored in this study and describe in the report are highlighted above. It is a distributed force, comprised of light and agile ground units and suites of remote sensors and shooters, all interconnected by a robust information infrastructure. We use the term situation understanding throughout the report to connote a higher level of knowledge than situation awareness.

An exploration of new concepts also generates an abundance of names for the concepts. We attempt a degree of consistency in the report by limiting ourselves to two names for the overall concept depicted above. We call it either a "new expeditionary force concept" or a "leading edge strike force." The second term highlights a particularly important rationale for the concept — to prepare the way for more extensive but slower arriving forces.

In the report we sometimes add the adjective "distributed" before expeditionary to emphasize this salient characteristic of the concept. Its distributed nature has several dimensions: the interdependence of the ground forces and remote suites of sensors and weapons, the posture of the ground force itself, and the posture of the basic unit within the ground force. We use the term "combat cell" to denote the basic ground unit of this distributed expeditionary force concept. Such cells may have different composition and capabilities depending on the nature of the mission and scenario.

Section II
Overview of Concept:
Rationale, Description, and Context

THERE IS A COMPELLING STRATEGIC RATIONALE FOR EXAMINING NEW WARFIGHTING CONCEPTS

- Rapid application of military force can deter, defuse, contain and stabilize

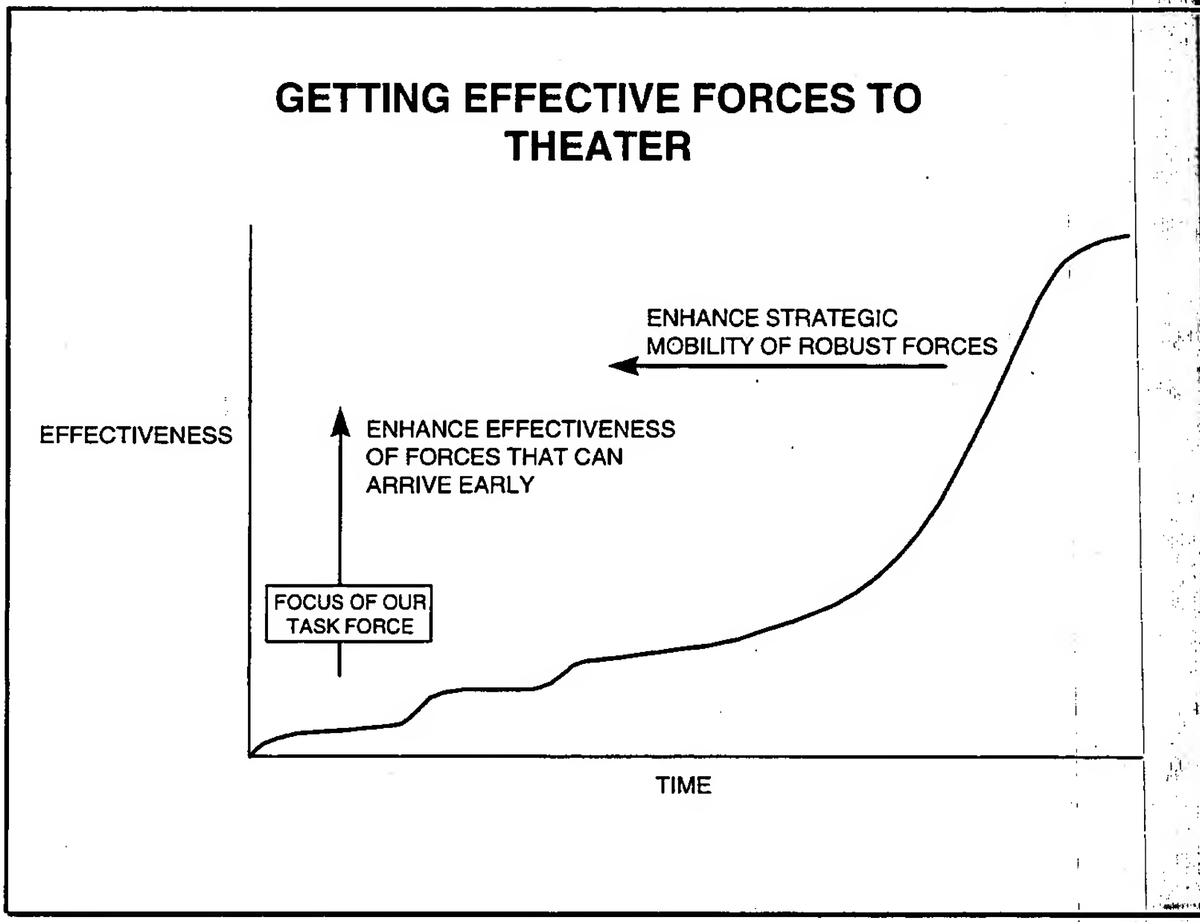
  However:

  - U.S. reliant on expeditionary forces (CONUS and sea-based)
  - Regional adversaries will have motives and means to delay/disrupt "traditional" deployments
  - More opportunities for urban operations
  - Adversary's own "revolution in military affairs" may seriously challenge evolving U.S. capabilities

> Greatly increasing effectiveness and decreasing vulnerabilities of rapidly deployable forces will enhance U.S. freedom of action to deal with this future

This Task Force did not spend a lot of time inventing futures. We assumed that the U.S. would retain global interests and commitments and that military force would remain a critical instrument of U.S. policy. In particular, rapid and effective application of military force can be a potent tool in the U.S. kit bag to deter, defuse, contain, and otherwise prevent bad situations from becoming much worse. However, the challenge is that the U.S. must do this in a world where we are likely to be reliant on expeditionary forces and face resourceful adversaries seeking ways to neutralize U.S. military prowess.

The 1995 DSB Summer Study posited future U.S. adversaries with both motives and means to achieve their military goals rapidly and make it very difficult for the U.S. to deploy forces in traditional ways to theater. The U.S. may increasingly face situations where our military leverage is perceived to be either too vulnerable or too slow. Thus, unless we can increase the effectiveness and robustness of rapidly deployable fire, the U.S. will lose considerable freedom of action to support its global interests.



This notional figure depicts a "traditional" force deployment to a theater. The build-up of forces during the Operation Desert Shield phase of the Gulf War took almost five months. Future adversaries may not give us that luxury again. The challenge of getting effective force there earlier is being addressed within DoD on several fronts: more strategic mobility, more prepositioning of materiel (ashore and afloat), and tailoring the forces to preserve effectiveness while enabling more responsive deployment and sustainment. This Task Force concentrated on time urgent contingencies and addressed how to make those forces that can arrive very early — within the first hours and days — much more potent than they are today.

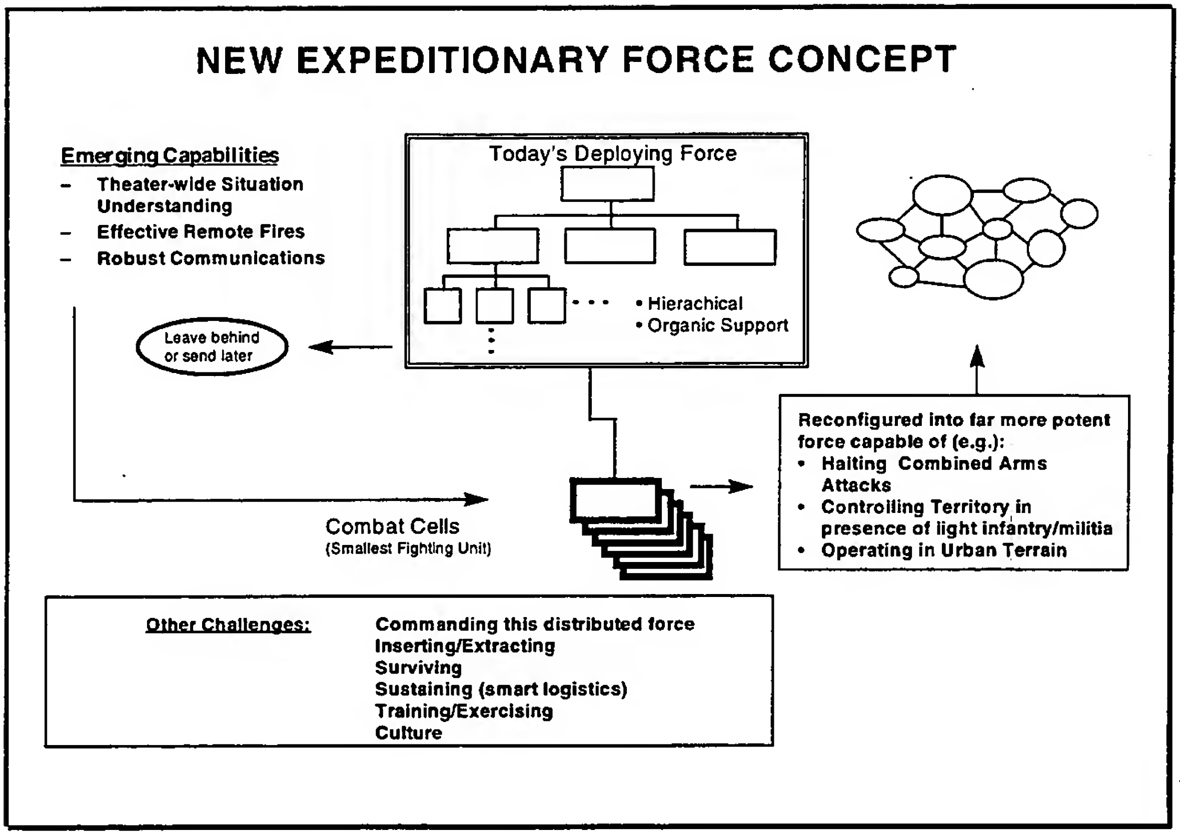
WE SET AMBITIOUS GOALS FOR THE EXPEDITIONARY FORCE CONCEPT

- > 10 fold increase in capability compared to today's light force
- Versatile; does Military Operations in Urban Terrain (MOUT), difficult terrain, halting combined arms attacks, locating and neutralizing WMD
- Comprised of superbly trained general purpose forces
- In place < 1-2 days
- Fight < 2 weeks
- Affordable
- Spinoff for other forces/missions
- Evolve during the next 20 years

These are an ambitious set of goals and it will be quite a challenge to fulfill them all. The order of magnitude goal of effectiveness enhancement reflects our desire for revolutionary rather than incremental improvements. Part of this enhancement (e.g., a factor of two) could come from increasing the percentage of actual combatants deployed on the ground in theater while leaving the non-fighting portion of the force behind but "connected" via the information infrastructure. Another factor of two or more could result from making these combatants more effective through tactics, training, and technology. Finally, the largest potential enhancements can derive from leveraging the situation understanding and effective fires provided by the remote suites of sensors and weapons.

We want this force to be as versatile as possible — able to take on a variety of missions in various environments. While these expeditionary forces we envision will have characteristics similar to today's Special Operations Forces (SOF), we place additional challenges (including training) by the objective of using general purpose forces. For the ground element of the force, this will involve the approximately 25,000 light infantry currently in the Active force (Army and Marine Corps).

The two week operating goal reflects that this force is not intended for sustained operations. They must be able to accomplish their mission quickly and either get out or be reinforced by later arriving forces, depending on the situation.



Our approach to meeting these ambitious goals is to exploit the synergies among three emerging capabilities whose ultimate potential is barely being tapped: theater-wide situation understanding, effective long range fires, and robust communication. We couple these to a fourth element, a ground force redesigned from the bottom up, starting with the smallest fighting unit (called a "combat cell" in this report).

The operational challenges to making this concept a reality include: (1) commanding and controlling the distributed force, (2) inserting and extracting it, (3) making it survivable, and (4) and sustaining it through smart logistics. Smart logistics techniques utilizing the robust information infrastructure will be needed to provide "the right stuff at the right place and at the right time" with vastly reduced logistics footprint and personnel in the combat zone.

The training and exercise demands of such a flexible and responsive force also pose formidable challenges. Lastly, there are cultural obstacles that always exist when large and established organizations attempt new ways of conducting its business.

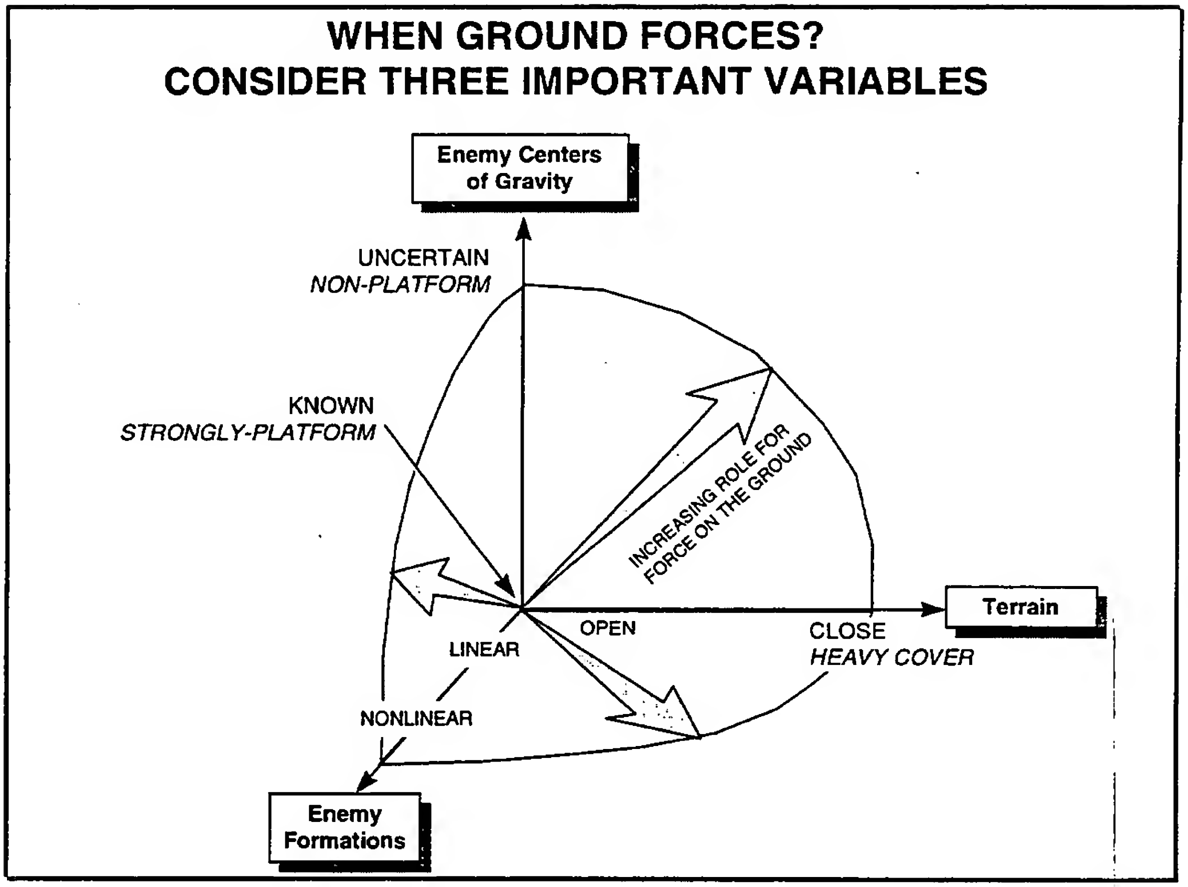
The Task Force examined how such a conceptual force could be applied in several operational environments including: (1) halting a combined arms attack, (2) controlling difficult terrain in the presence of light infantry/militia, and (3) military operations in urban terrain (focusing on specific military missions such as locating and neutralizing WMD, rather than sustained "peace keeping").

CRITICAL ROLES FOR AEROSPACE & SEA FORCES

- Gain superiority or dominance, if possible
  - Air, Sea, Undersea, Space
  - Information (dominance essential)
- Provide reconnaissance, surveillance, & targeting
- Deliver Fires
- Deliver & sustain forces ashore

Air and naval forces are necessary elements of this expeditionary force concept. They must provide the air, sea, and space superiority; reconnaissance, surveillance, and targeting; delivery of fires; and delivery and sustenance of forces ashore that are all required for this concept to operate successfully.

Gaining of information dominance is particularly critical for the concept and will involve offensive and defensive information warfare, including deception, decoys, and electronic combat.



One of the questions we wrestled with is "Why and when do you need ground forces?" This figure illustrates three of the variables that affect the answer.

As the terrain goes from open to closed, as the enemy's order of battle moves from linear to nonlinear, and as the enemy's center of gravity moves from a known, platform-orientation to uncertain, non-platform, the Task Force believes that there is an increasing role for ground forces.

In such a case, ground forces are important to achieving situation understanding sufficient to accomplish the mission: to fill in gaps in the coverage of remote sensors, to distinguish enemy combatants from neutrals, to help detect and target dismounted forces that present difficulties for remote sensors, and to resolve ambiguities about target characteristics necessary to support effective remote fire. They could also secure Points of Debarkation (PODs) and complement (provide force multipliers) the local friendly forces.

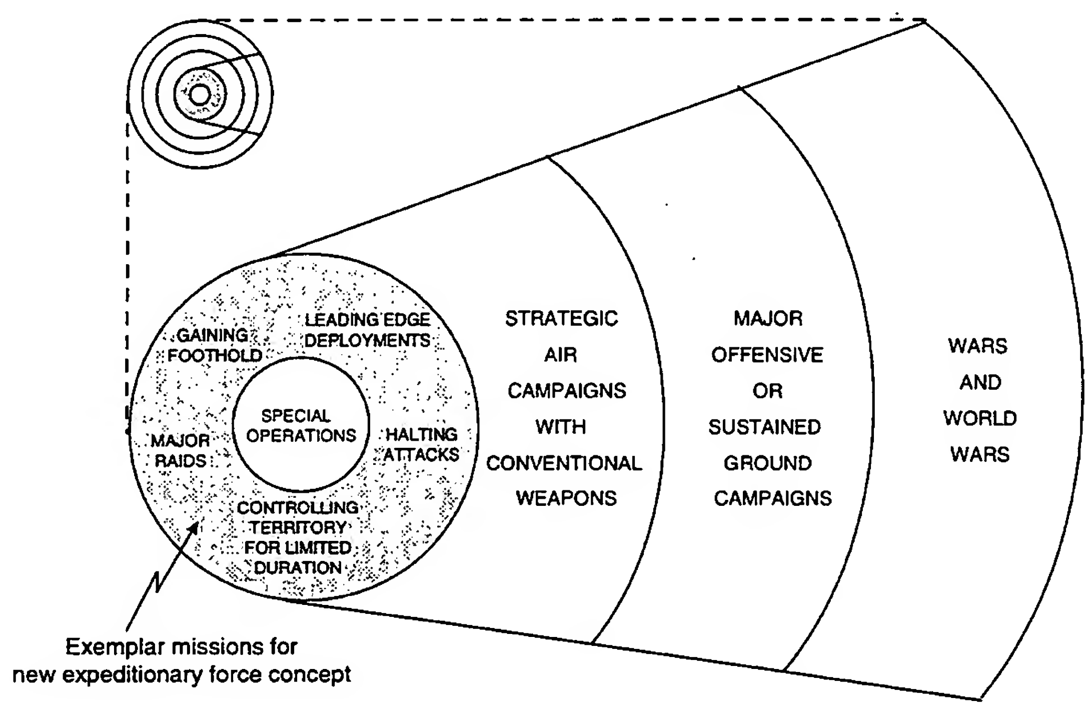
The most likely and frequent cases for U.S. military operations will not be independent U.S. actions, but will involve coalition or other friendly forces. How to integrate these forces into the concepts we espouse will require more analysis than could be applied during this Summer Study. Coalition forces can contribute shooters, sensors, intelligence, lift and sustainment, and, in some cases, may be able to substitute completely for U.S. ground

forces. Training and equipage implications must be addressed and the information infrastructure designed to accommodate a wide range of possible contributions from and integration with coalition forces.

In some cases, the application of U.S. air and sea based fire power would precede the arrival of U.S. ground forces. In other cases, the rapid insertion of forces, including ground elements, into a threatened nation could help stabilize the situation and deter aggression. The deterrent effect is strengthened to the extent that the inserted force is perceived as militarily effective (as seemed to be the case for the Vigilant Warrior exercise in the Fall of 1994 when Army units were rushed to SWA to link with their prepositioned equipment in response to Iraqi southward troop movements).

Within the ground force, our focus was on the "combat cell," the smallest fighting unit above the individual level. We focused on the cell rather than larger entities because of our desire to achieve effective operations in very dispersed postures. We focused on the cell rather that the individual because we believe that such cells can achieve far greater leverage from new technology and innovative tactics. These small units are also building blocks for larger units and, thus learning how to enhance the performance of the combat cell will have applications other than rapid deployments. Finally, compared to other elements of our military, the light infantry combat cell receives relatively little attention and resources and probably has changed the least over the last half century. Today, there is great potential for profound improvement, particularly from new operational concepts and tactics enabled by the revolution in information technology.

WE ARE ADDRESSING A SUBSET OF FUTURE APPLICATIONS OF MILITARY FORCE



Where does this concept fit into the spectrum of military operations that the U.S. may be called upon to conduct in the future? Consider a "slice" of future applications (not exhaustive) of military force, shown in the figure.

The type of force we are talking about clearly is insufficient to conduct major offensive or sustained ground combat campaigns. However, as already noted, a capability for rapid and effective use of military force can contribute to deterring and preventing these larger conflagrations.

At the other end of the spectrum, the missions of the expeditionary force will, in general, be of a larger scale than those of the SOF and be overt rather than covert. However, the expeditionary force concept borrows from SOF operations and blurs the distinction between SOF and general purpose forces.

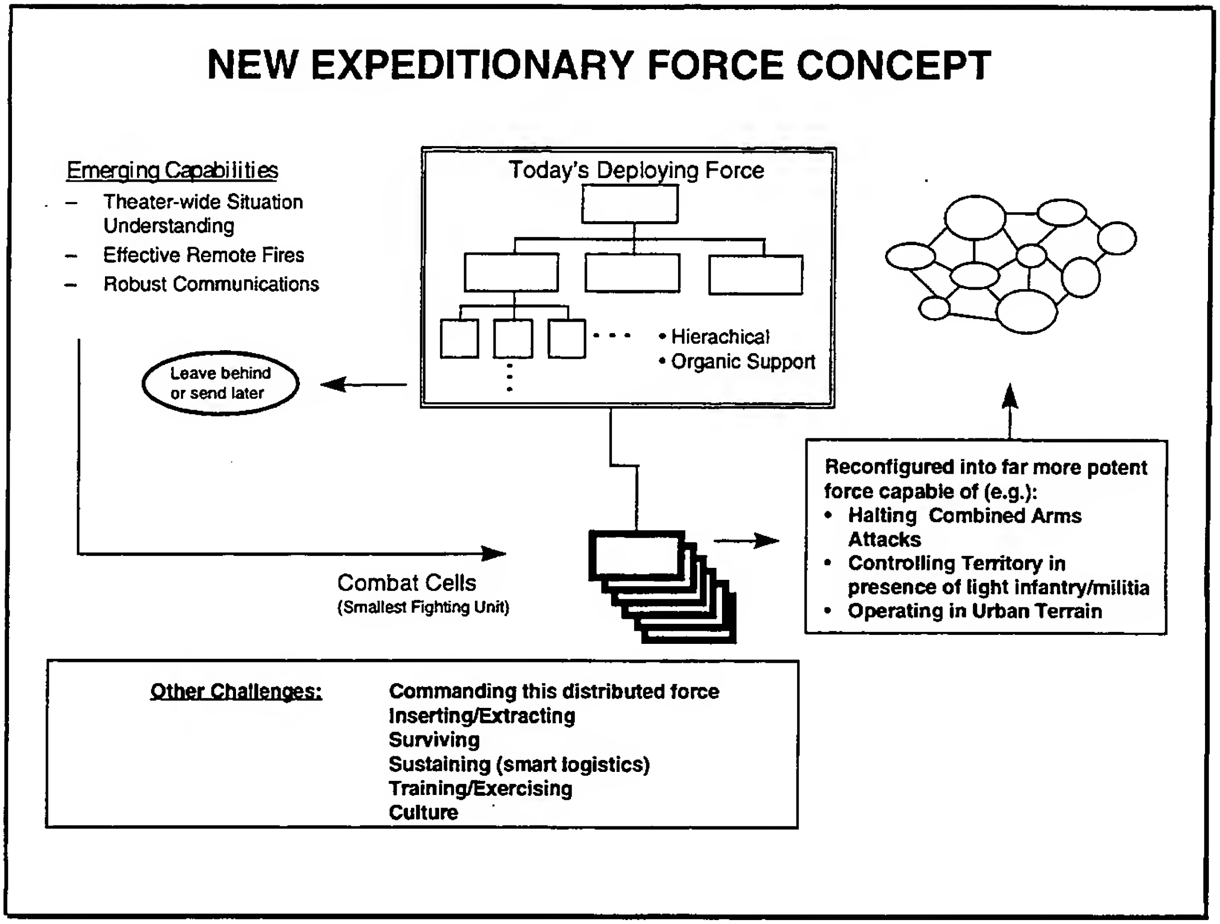
Air campaigns — before and after insertion of ground units — are a critical part of the expeditionary force concept. In some cases, depending on the mission and the circumstances, the air campaign will be sufficient by itself to achieve the objectives (or air strikes might be all that the U.S. would be willing to employ given the stakes and risks).

The relationship of air campaigns to the missions of the expeditionary force (as a stand-alone capability or as a precursor or complement to the insertion of U.S. ground forces) deserves more consideration than we were able to give it during the Summer Study. For example, it is not unreasonable that the desired effects and outcomes of an air campaign that would precede the insertion of these distributed light ground forces, would be substantially different from those we have conducted in the past.

IN SUMMARY, OUR CONCEPT IS ABOUT MASSING FIRES NOT FORCES

- Joint Strike Force with robust remote elements
  - as much as possible, move bits, not atoms, to the theater
- Rapid deployment of light agile combat cells
  - linked to each other and remote resources
  - dispersed, avoids direct fire fights but with self protection
  - configurable into larger units
- Use humans only when necessary
  - much more UAVs, robotics
- Situation understanding dominance which includes
  - robust information infrastructure
  - CEC-like understanding of the ground battle
  - critical role for sensors / information management
- Ensemble of effective remote fires
  - no single "silver bullet'
  - responsive. affordable
  - important role for loitering weapons, inflight update
- Low profile responsive sustainment
  - get the right stuff to the right place at the right time
- Affordability from a mission perspective, not size of the force
  - missions are "strategic," even though the forces are "small"
  - the expeditionary force is the JTF (at least until larger forces arrive later)

The key features of the concept — highlighted in the above chart — are discussed in the following sections. Additional elaboration is provided in Volume 2 and 3 of the report.



In Sections III and IV, we briefly describe applications of this new expeditionary force concept to different missions: (1) a leading edge strike force capable of halting combined arms attacks, (2) controlling territory in the presence of light infantry/militia, and (3) operations in urban terrain. (These are covered in more detail in Volume 2, Section I-III.) Then Section V summarizes how the emerging capabilities and the challenges enumerated in the above chart can fit together to support this force concept. The enabling technologies are further discussed in Appendix C of this volume. Sections VI and VII present the Task Force's recommendations and conclusions.

Section III
Operational Considerations

OPERATIONAL CONSIDERATIONS

"The sooner an intervening force can arrive to influence the course of military events, the smaller the chance that the conflict will devolve into a fire-power-intensive wasteful slugging match,"

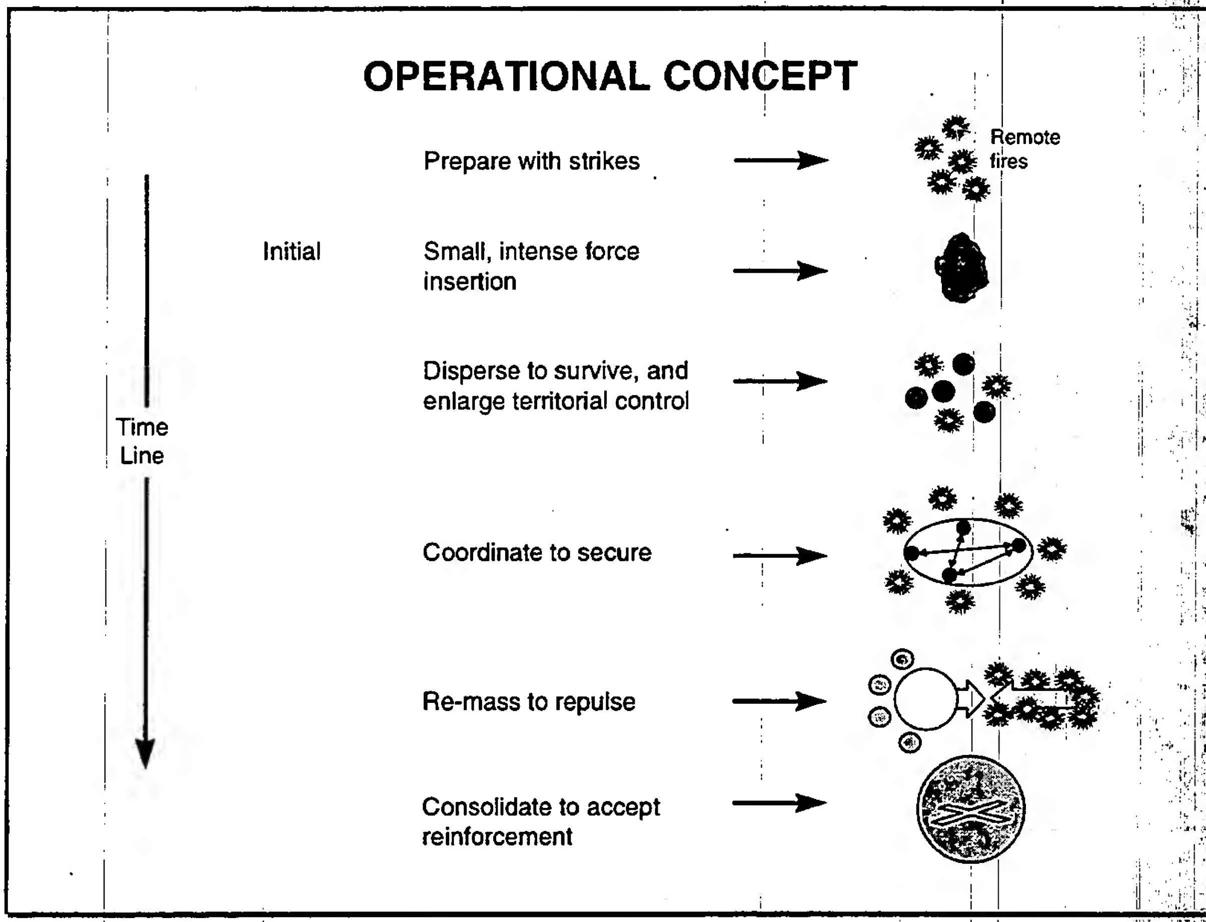
MG Robert H. Scales, Jr.., USA

In this chapter we discuss how the concept outlined in the previous chapter might operate in several environments. Although size and composition of the force depend on the mission, there are two common features of the proposed concept: dependence on remote elements, and ground forces organized around agile combat cells. We explored concepts with in-theater ground forces up to ~5,000 (brigade size). The total force including the air and sea elements could be considerably larger.

The chapter begins by illustrating the general operational concept and then discusses:

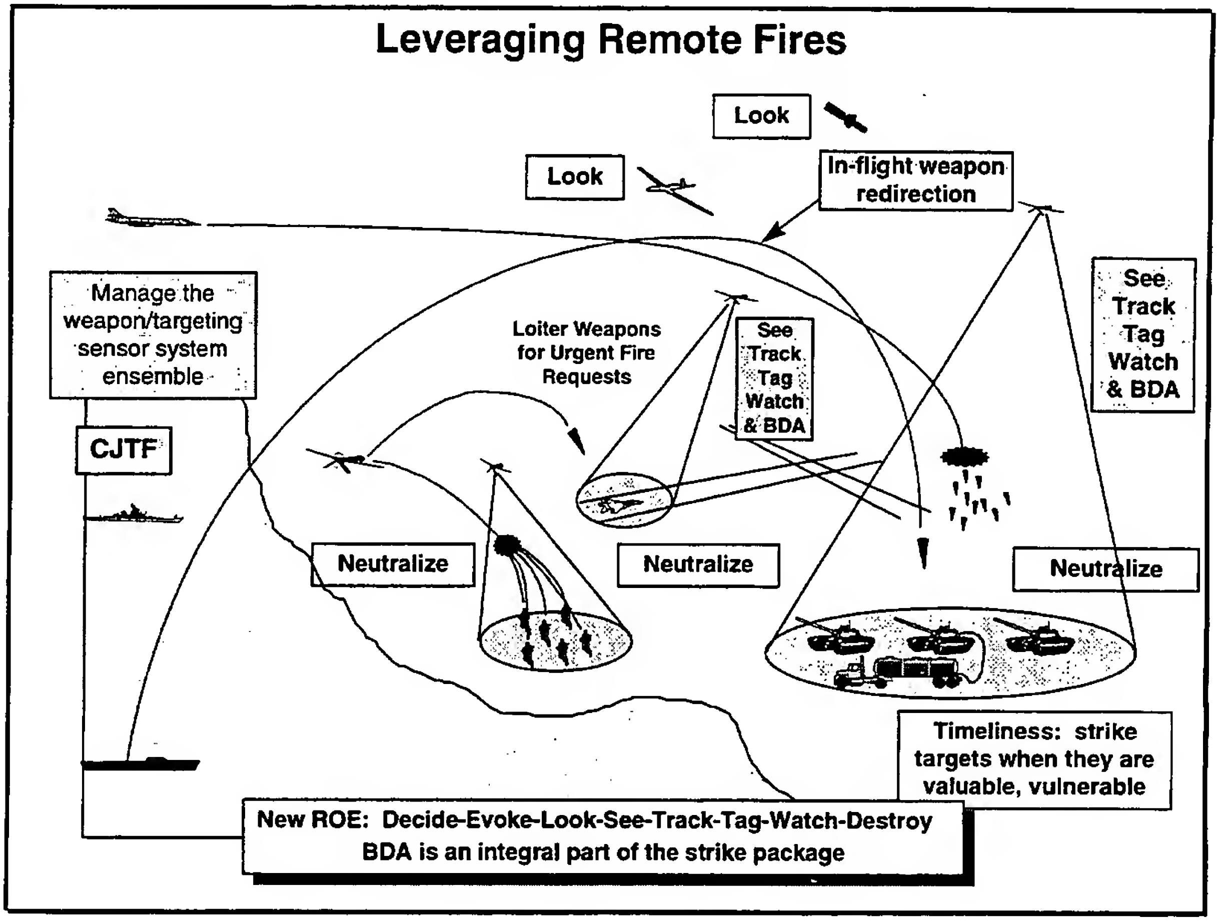
- the critical role of remote fires to this concept,
- an approach to achieving dominant situation understanding,
- how the combat cells could operate to control territory,
- a top level view of how a future brigade size expeditionary force might be organized,
- potential enemy countermeasures to the concept, and
- the special case of operations in urban terrain.

General Operational Concept



This figure depicts a general time line of operations of the expeditionary force concept. Depending on circumstances, the insertion of the ground units would be preceded by strikes and suppression of enemy air defenses using air and naval forces. Again, depending on the particular circumstances (political situation, availability of ports and local airfields, enemy disposition), the initial ground force would then be inserted in either dispersed or concentrated configurations. Subsequent operations could be conducted in widely dispersed postures (much more dispersed than today's norms) to increase survivability and enlarge territorial control or more consolidated postures to secure lodgments or other objectives.

The Critical Role of Remote Fires to this Concept



This graphic highlights several issues in the employment of remote fires under the new expeditionary force concept. First, the expeditionary force must have the real-time capability to manage ensembles of both sensor and weapon systems including a means to deconflict weapon employment and the ability to call for specific weapons that match the target characteristics when it is needed.

Second, there is a critical role in the weapons ensemble for loitering weapons and inflight updates in order to provide the responsiveness needed to deal with time urgent and mobile targets. The ensemble of indirect fire weapons must be capable of engaging any tactical targets.

Third, the Task Force envisions new rules of engagement which employ means to evoke targets (fires, information warfare, etc.) that can then be observed, put into track, and "tagged" (to be described in more detail later). These will permit the force commander to schedule fires to hit targets when and where they are most valuable and vulnerable.

Fourth, the battle damage assessment function must be integral to the strike package and, in some cases, integrated into the strike weapon itself.

"Information Based Warfare" is an apt title for these operations, because the essential key to success will be exquisite situation understanding.

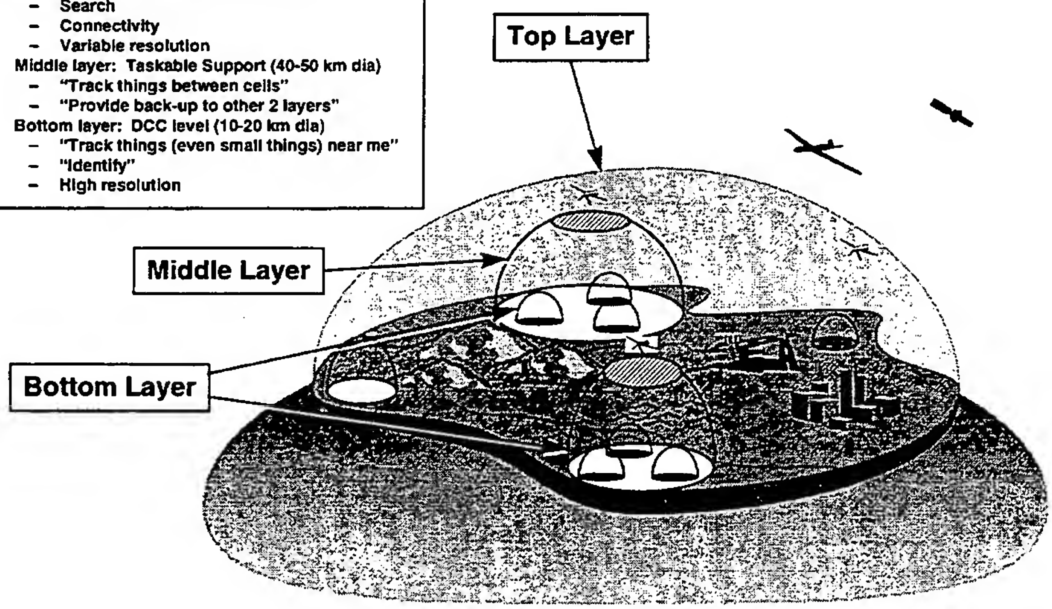
VALUE OF FIRST ROUND INDIRECT FIRE KILL

- The greater the surprise the more vulnerable the target
- Old concept = see - shoot - adjust - kill a few?
- New concept = evoke - look - see - track - tag - watch - destroy/neutralize
- Potentially great value but difficult to quantify
  - could be 1-2 orders of magnitude benefit
- Drastic reduction in ordnance requirements

Our objective is to achieve high effectiveness from the first round of indirect fire. This has rarely been the historical experience. Indirect fire weapons usually have operated on a doctrine of see, shoot, adjust, and shoot again. Such a sequence provides the enemy with a warning that says, "Stop doing what you're doing, and get under cover because I'm going to fire at you." Conversely, if the enemy believes he is secure and is not under observation, then an effective and well placed weapon can catch him unaware and in a potentially far more vulnerable posture. Offensive Information Warfare (IW) can play an important role in evoking targets and fostering surprise. Thus we want to convert "See-Shoot-Kill-Maybe," into "Evoke-Look-See-Track-Tag-Watch-Destroy," with a strike that the enemy does not expect, and at a time and place that he is most vulnerable or valuable. A future operational commander able to decide when best to attack enemy units and thus able to use the limited weapons resources far more efficiently than today is critical to the success of the concept.

EFFECTIVE SITUATIONAL UNDERSTANDING IS ACHIEVED BY THE INTEGRATION OF MULTILAYERS OF SURVEILLANCE AND CONNECTIVITY

- Top layer: CJTF level (300-400 km dia)
  - Search
  - Connectivity
  - Variable resolution
- Middle layer: Taskable Support (40-50 km dia)
  - "Track things between cells"
  - "Provide back-up to other 2 layers"
- Bottom layer: DCC level (10-20 km dia)
  - "Track things (even small things) near me"
  - "Identify"
  - High resolution



The three layers shown are notional -- there could be more.

This chart shows how the Task Force foresees the multilayered suite of sensors that will be needed to provide enhanced situational understanding at all levels of command down to the individual combatant.

The top layer provides a synoptic theater view of what is going on. The middle layer provides higher resolution to support targeting of remote weapons and combat cell operations. The bottom layer "belongs" to the combat cell and complements the information generated by the other layers to fill in gaps in coverage, help resolve target ambiguities, distinguish targets from non-targets, provide fire control quality tracking, and in general, allow the combat cell to have a decisive situation understanding edge over the adversary. This bottom layer "bubble" would include unattended ground sensors and elevated sensors under direct combat cell control.

In practice, the tasks of the different layers will not as neatly separate as depicted. In particular, some of the sensors in the top layers will be capable of very high resolution

detection and tracking in certain circumstances, and thus, can directly support long range fire and combat cell operations.

The top layer will be comprised of a variety of sensor systems (Signals Intelligence (SIGINT), Synthetic Aperture Radar (SAR), Moving Target Indication (MTI), Foliage Penetration (FOPEN) SAR, Electro-optical (EO), multi-spectral imaging) on a variety of platforms (satellite, aircraft, and high altitude unmanned aerial vehicles (UAVs)). It will provide a field-of-regard encompassing the theater of operations (hundreds of km in diameter). The intermediate layer could be provided by Medium Altitude Endurance (MAE) UAVs (e.g., PREDATOR-type) also carrying a variety of sensor types capable of providing better than one meter resolution over approximately a 40 km field of regard.

The bottom sensor layer includes an Advanced Air Vehicle (AAV) provided to each combat cell. We envision this Vertical Take-off and Landing (VTOL) UAV platform can service an area within a 10 km radius of the combat cell. It could carry a multi-spectral sensor system with 1 foot resolution over about a 300x300 meter square to detect vehicles and people. This AAV sensor system could also respond to cueing from the unattended ground sensors (UGS). A robust information infrastructure would provide the horizontal links to enable combat cells to use their sensors cooperatively. Such cooperation and the availability of information from the other layers may contribute to keeping the AAVs duty cycle relatively low and spending most of its time on the ground waiting for its few daily missions (and therefore reduce the logistic burdens of power supplies and fuel).

What is clearly implied is that U.S. forces have suppressed enemy air defenses and achieved air superiority in order to deploy such a tiered surveillance and reconnaissance network.

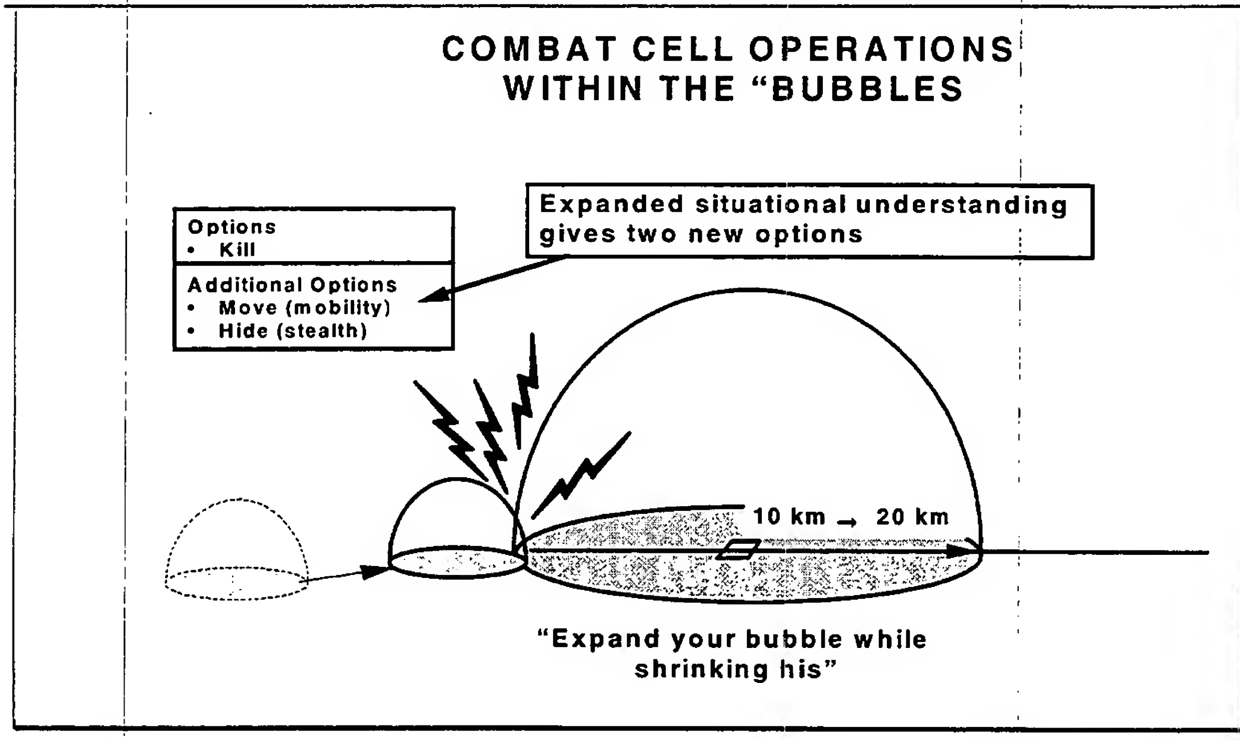
As will be discussed later, the real-time management of this theater sensor suite, coordinated with external national sensor systems, will become a critical and challenging task for future commanders. The theater commander will need at his disposal a Battlespace Integration and Management Capability (BIMC) that correlates, fuses, sorts, and distributes relevant information to his distributed elements including the combat cells. The BIMC should be integrated with weapons ensemble management capability to coordinate, deconflict, and manage indirect fires. The Theater Battle Management Core System (TBMCS), in early development by the U.S. Air Force, could be an appropriate place to develop the sensor and weapons management functions among other capabilities for planning, battle management, and situation understanding support.

The proposed Expeditionary Force Concept leverages the situation understanding obtained through this "layered" sensor approach to enable effective remote fires and militarily useful combat cell operation.

CONTROLLING TERRAIN: AN EXAMPLE CONOPS

- Insert combat cells (each cell is 10-20 men) to control territory on its own and/or secure territory and POD's for arrival of larger forces
  - Distribute cells over area to cover key nodes, intersections, and access routes
  - Provide cell mobility via foot or special vehicle, depending on terrain and situation
    - If on foot, each combatant load <35 lb, vice 80-90 lb today
- Situation understanding via "layered bubbles"
- Linked to ensemble of remote weapons
- Provide no concentrated targets for the enemy
- Stealth, reliable communications, IW essential for survival
- Cells avoid direct firefight
- Can coalesce into larger units if necessary

The combat cell concept, including its applicability, and potential strength and vulnerabilities, is covered in considerably more detail in Volume 2, Section 2.



A key capability for combat cell mission success is maintaining a local awareness bubble larger than the enemy's. The expanded bubble enables the combat cells to detect and monitor enemy actions well before being detected themselves. This places the critical advantage of time for action with the combat cell. Coupled with enablers for stealth, information warfare (IW), and mobility, the combat cell also has at its disposal several options for action: (1) enemy engagement/kill; (2) hiding while continuing to observe the enemy, or (3) moving to a safer or more advantageous vantage point. Options (2) and (3) are the ones that allow indirect fire to become the primary enemy kill approach.

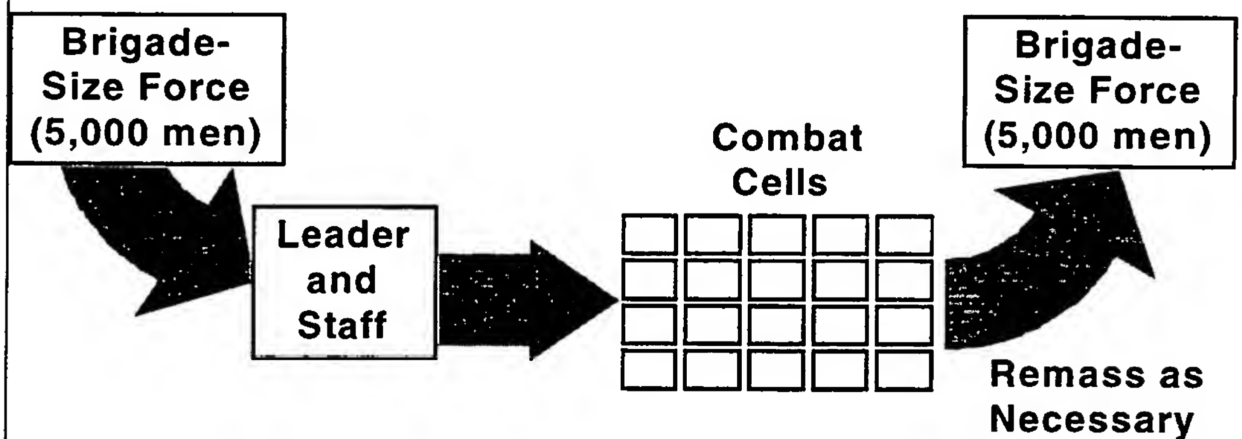
Conversely, when the combat cell's bubble shrinks to the same size as the enemy's and, in the extreme, becomes limited to the collective human senses in the cell, then all options collapse to simply "kill or be killed." The situation becomes one of who-sees-whom-first, and survival overwhelms any other task the combat cell had set out to accomplish. Inevitably, this becomes a losing proposition for the combat cell, being well within enemy territory where reinforcements for the enemy are much less problematic than for the combat cell.

The situation awareness bubbles, along with reduced signature of any insertion vehicles, are needed for insertion of the combat cells. If our forces are entering a hostile situation, the need for overhead "spotlights" to find areas where the cells will have some "safe time" is critically important.

Buying this first hour undisturbed on the ground can make the combat cell the "owner" of a certain piece of territory employing sensors and learning his land. The longer the cell is there, undisturbed, the more it can "grow its bubble." If the bubble is to move, it should be led by a spotlight that says, "OK — you can move West/Northwest 6 miles: there's nothing there." The size of the bubble determines the cell's options: the bigger the bubble, the more options it has.

A Top Level View of How a Future Brigade Size Expeditionary Force Might Be Organized

ORGANIZATION DESIGN CONCEPT



- **Trained, equipped and manned to operate as brigade, and as dispersed combat cells**
- **Flexible combat/support tailoring**
- **Combined arms synchronization**
- **Employ long range precision fires**
- **Reduced C2 layers**
- **Integrally connected to the situational awareness infrastructure and remote firepower that provide the force multipliers needed to defeat heavy opposing forces**

Combat sells could be organized into "brigade" sizes under certain conditions. This chart depicts the organization of such a "brigade" size "Leading Edge Strike Force," deploying rapidly to theater to establish an initial defense and provide for the introduction of follow-on forces. Their mission, in concert with indigenous forces, would be to deter aggression, and if deterrence fails, halt or at least delay enemy forces and prevent seizure of air and sea points of debarkation (APOD/SPOD).

The ground component of such a force would be comprised of 3-4 battalions of light infantry (about 100-200 combat cells total). Other components of the ground force could include civil affairs/psychological operations, intelligence, engineers, command, control and communications as well as some organic indirect fire and attack helicopter capabilities. Combat service support would be limited to the minimum needed to accept and distribute on-time precision logistics. The strike force could operate in both concentrated and highly dispersed postures to perform a variety of missions: surveillance and reconnaissance, seize, secure, coordinate, and integrate with coalition forces.

A 5000 man expeditionary force with these capabilities could arrive (if uncontested) in theater via approximately 300 C-17 sorties. It would then disperse, and in concert with indigenous and coalition forces, establish an internetted sensor and information grid linked to other theater and national systems. It would then be integrated with indigenous/coalition forces, deploy to defensive positions, conduct reconnaissance and IW operations, refine target and fire plans and perhaps conduct battalion level rapid reaction operations (coupled to the remote elements of the force) for rehearsal and demonstration effect.

At the individual and combat cell level, planning, rehearsing and adapting would be a continuous process enroute and while in-theater. Their mission planning/rehearsal will include the actual terrain, real time video and other sensor output and digital language translators to facilitate working with coalition forces and HUMINT sources.

One vision of the concept views the light task force as a component (possibly augmented as described above) of a future standard light division that is not specifically configured, equipped or trained as a Leading Edge Strike Force. The capability of these units to conduct this mission would then depend on technologies, doctrine, techniques and training available in the general purpose force structure. New technologies and training techniques should allow these units to have very rapid learning curves about the specific area and adversary characteristics before, enroute and during deployment to theater. When the larger follow-on force is deployed, the Leading Edge Strike Force could be integrated back into its parent division. Experimentation will be required to determine whether this concept is practical or whether a more specifically equipped and trained task force is needed.

FREE MORE LIFT FOR COMBAT OPERATIONS BY REDUCING SUPPORT FUNCTIONS DEPLOYED TO THEATER

Brigade Size Task Force Lift Allocation

	Combat	Support	Total
Today	40%	60%	100%
2015 goal	80%	20%	100%

Candidates for reduction:

- Sensors & Intel Function (Reachback)
- C4ISR Infrastructure
- Ammunition — Precision Technology & Theater Fires (Organic & Support)
- Telemedicine and Biomedicine
- Logistics
  - Total Asset Visibility & Containers
  - Tailored Maintenance & Improved Reliability
  - Direct Precision Delivery & In-Theater Conversion
    - Food, Fuel, Water, Power
- Reduced Tactical Mobility Footprint
  - Fuel, Power Supply, Materials

Today, movement of even light forces requires significant time and transport resources. Although each contingency will have a different schedule for deployment, as a general rule, a brigade requires a week to deploy, a division about a month, and a corps up to 3 months to completely close into an operational area.

Reducing the support portion of the deploying force will free more lift resources to be allocated to actual warfighting. Our goal is to reduce the support lift allocation from today's ~60 percent of the total down to only 20 percent. Candidates for reduction include sensor and intelligence functions and the C4ISR infrastructure. These functions could be effectively provided remotely via the information infrastructure with greatly reduced on-the-ground support in theater. The emerging capabilities in telemedicine will also enable a reduced logistics footprint, while providing effective medical and casualty care services. Additional reductions can derive from tailored logistics and maintenance making use of total asset visibility, improved reliability, direct precision delivery to the units and in theater conversion (food, fuel, water, power). Technology can contribute to reducing the tactical and strategic mobility footprint of fuel, power supplies, and materials.

The most important source of the reduction of lift allocation to support will be the availability of effective remote fires. This, along with increased effectiveness of organic weapons, will permit the initial deployment with far less weapon and ammunition loads than are needed today.

We have postulated a goal by 2015 for the Leading Edge Strike Force to close and be prepared to conduct operations within 48 hours. Similarly, this implies that future goals for larger units also should become more demanding, (e.g., one week for a division, and one month for a corps to complete a deployment to a contingency area).

THERE ARE FOUR SEPARATE POTENTIAL ORDER-OF-MAGNITUDE GAINS IN THE EXPEDITIONARY FORCE CONCEPT

- Layered, integrated, "all seeing" situational understanding
  - increases "area of control"
  - decreases number of forces needed
- Effective remote fire (accurate, affordable)
  - reduces logistics burden
- Kill at will
  - choose time to engage, maximize effects
  - one shot kills, strong psychological impact
- Reduced casualties
  - fewer people in harm's way (although not by itself a guarantee of reduced casualties)
  - stealth/warning

This Task Force's expeditionary force concept provides the four separate, but not independent, "order-of-magnitude" improvements over current operations listed above.

Improvement in area covered per person is achieved by the layered (tiered) "bubbles" providing situational understanding and the reduction of personnel associated with direct fire, because the concept assumes virtually all fire is indirect.

Remote fires effective against all classes of targets will be the most important contributor to making a light force into a potent force.

The lethality of this concept is enhanced by choosing the time of attack (for example, when the enemy is refueling or gathering for meals). The concept of first-shot-kills, achieved by GPS aided precision and proper choice of time, restricts the enemy's opportunities to reduce his vulnerabilities, and also provides a potentially large, psychological impact.

These improvements are supplemented by a reduction in casualties because we are deploying fewer people and giving those people the option of moving, hiding, and generally avoiding threats. This is quite different from forcing them to become targets because we insist they bring direct fire or engagement to the enemy.

However, to achieve these gains the concept must prove robust to enemy countermeasures.

Potential Enemy Countermeasures to the Concept

ADVERSARIES WILL SURELY ATTEMPT TO DEVELOP COUNTERMEASURES

- These will include:
  - tactical measures not requiring high technology or new forces
  - changes in forces or operations
  - more advanced technologies
- They may use all these approaches to:
  - attack and degrade the situation understanding "bubbles"
  - neutralizing the combat cells
  - prevent insertion/sustainment
- The worst "countermeasure" may be reality
- There are potential counter-countermeasures that can keep the concept viable
- An energetic Red Team effort must be an integral part of the process to develop these new distributed force concepts

The enemy has strong motivation to attack the situational understanding "bubbles" that provide the concept with superior and longer-range understanding of the battlefield situation. If the enemy can reduce the range and/or effectiveness of the situational understanding bubbles, the effectiveness of the concept could be drastically reduced.

Their methods could include jamming GPS and communications; attacking UAVs; using cover, concealment, deception, and other forms of IW to distort our situation understanding; co-mingling combatants and non-combatants to complicate targeting and strike; and capturing intact U.S. equipment that displays situation awareness. There are potential counters to reduce the vulnerability of the concept to these countermeasures. Some are being worked vigorously today (counter GPS jamming), others will require more attention (UAV survivability). The use of some of these countermeasures will, moreover, restrict an adversary's ability to conduct offensive operations.

Experience from Vietnam suggests that teams similar to the combat cell's can survive (e.g., STINGRAY). Furthermore, the postulated architecture for situational understanding

incorporates many layers of redundancy with the smallest "bubble" (e.g., snipers/observers, LUGS/UGS, micro UAV's, VTOL UAV), and also taskable layers above the first-tier bubble that can provide on-demand back-up to local bubble problems. We do not believe that the loss of a few cells would lead inevitably to a catastrophic failure of the overall dispersed force mission.

Another class of countermeasures to the combat cell concept involves approaches for neutralizing the combat cells. The enemy could form many search-and-destroy teams using dogs, UGS/LUGS and/or UAV's to detect and track the movement and operations of the combat cell's. Enemy units could use random and inadvertent interactions between their population and the combat cell's to leverage information gathered by remote sensors to find and target these operations. A large, indigenous militia can be used to detect and attack the combat cell units.

Countering these countermeasures will depend on ensuring that the combat cell's situational understanding is superior to the enemy's. The combat cell's can use self-defense, stealth, and mobility to remain covert. Other tactics could include the use of IW against the enemy's UGS/UAV net, active spoofing to increase the enemy's search area, hunter-killer UAVs to negate enemy UAV operations, and active jamming of enemy GLONASS and GPS receivers. Combat cell sniper operations against armed militia and other aggressor forces could reduce their operational effectiveness and might lead to a catastrophic break in their will to fight. External PSYOPS can be used to influence the actions of non-combatants and militia forces to degrade their support of enemy operations against combat cell units.

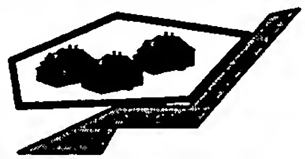
The enemy could also attempt to prevent/disrupt the insertion and sustainment of combat cells. Insertion aircraft could be attacked with distributed air defense assets, low-technology barriers could be erected on likely ingress routes, potential insertion sites could be monitored, and theater support bases (land and sea) could be targeted with long-range, wide-area weapons.

Potential counter-counter measures include signature reduction of insertion/sustainment vehicles, remote insertion, new active and passive defenses (including chem/bio defense), and increased capability for extended range (extra-theater) operations. Insertion/sustainment/extraction vulnerability can be further reduced if the mission duration of combat cells can be substantially increased from the 3-4 day historical norm.

The Special Case of Operations in Urban Terrain

MILITARY OPERATIONS IN URBAN TERRAIN (MOUT)

Vietnam (Hue City)
- Walled city, small bldgs, river people



Lessons Learned
- *Poor Comm*
- *Stressed C2*
- *Casualties 6x normal*
- *80% of city destroyed*
- *Leaders/Marines not trained for urban warfare*

Today (Grozny)
- Large buildings, ancient infrastructure sizable populace

Current Situation
- *Poor comm*
- *Stressed C2*
- *High casualties (mil & non-combatant)*
- *Most of city center destroyed*
- *Poor conops / untrained soldiers*

Not Much has changed

- Even more significant and difficult in future
  - Urbanization ⟶ political instability
  - Cities are where power resides
  - Enemy exploitation of non-combatants limits our options
  - WMD sites in urban areas

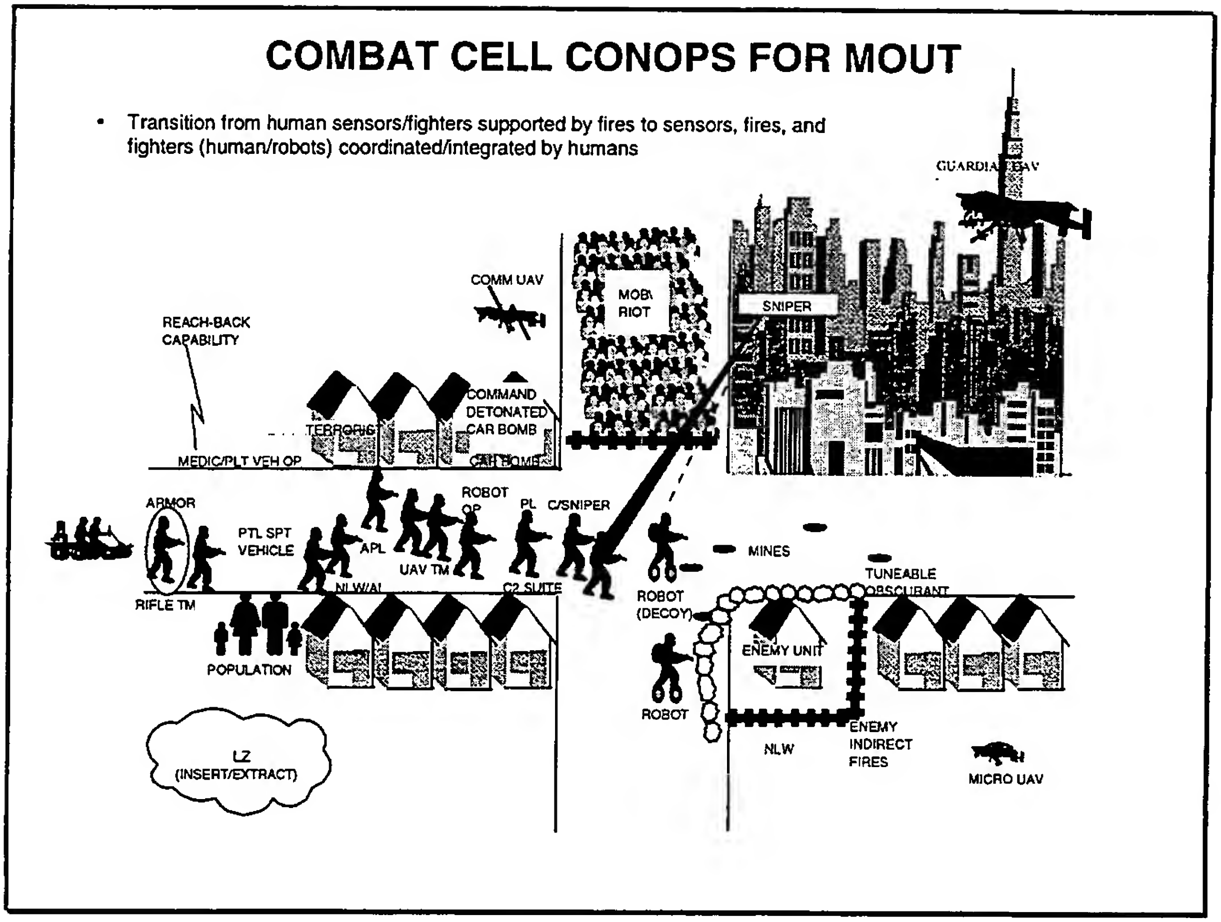
The experiences of past and recent military operations in urban terrain indicate that not much has changed. Poor communication, constrained mobility, stressed command and control, and high casualties continue to be the norm. The urban environment is a particularly difficult one for military operations and the challenges it poses are well known.

The rapid growth of the number and size of urban centers, especially in regions of political instability, increases the likelihood that U.S. forces will be called upon to conduct MOUT.

For the purpose of our Task Force, the MOUT missions we addressed were not pacification or sustained peacekeeping, but rather more limited duration operations with specific military objectives. These could include freeing hostages, seizing leadership or destroying critical C3 or other high value hard targets. Speed will be essential for these missions: get in and move rapidly, accomplish what you came to do and then get out as quickly as possible. The rapid operation — closer in tempo and preparation to a SOF operation than

to a typical ground maneuver — must be based on detailed intelligence, mission planning, and rehearsal for the critical elements.

The Task Force focused on a particularly challenging MOUT mission, one unfortunately that the U.S. may increasingly face, locating and neutralizing WMD capabilities (production, storage, delivery, C3). The reaction forces of the adversary must also be delayed or neutralized until the WMD search and destroy operation is completed. An example of such operations can be found in Volume 2, Section 2 and in Volume 2, Part 2 (classified), developed for this Task Force by USSOCOM.



Similar to the previously discussed environment, our concept for MOUT involves light, agile and situationally aware combat cells coupled to remote sensors and fires and supported by precision logistics. In this case, the very nature of the terrain dictates small combat cells. The challenge is how to enable the cells to get the job done with minimal casualties. We envision a transition from the past CONOPS of human sensors/fighters supported by fires to one characterized by sensors, fires, and fighters (humans/robots) coordinated and integrated by humans.

We configured a combat cell tailored for this mission (depicted in the figure above). It would consist of 12-19 individuals. The cell and assistant cell leaders could also serve as the C4 node and demolition/CW/BW specialist. In addition to counter snipers and riflemen, a language/psychological operations specialist, a medic, and vehicle operators, the cell would include several UAV and robotics operators. Cross training in all skill levels will be the norm.

Critical enablers include:

- An information infrastructure that provides assured communication in a tough environment, a common reference grid (so troops can communicate locations of objects), and a means to distinguish between friend, foe, and non-combatant;
- Sensors for area surveillance, counter sniper and through-wall observation;
- UAVs for surveillance, communication relays, and as a loitering platform for rapid response fire;
- Weapons ranging in lethality from less than lethal to anti-armor;
- Tools and weapons to neutralize buried facilities and WMD stocks; and
- Precision and on-time logistics, particularly to deliver these tools and weapons rapidly rather that having the cells carry them with them as they search for the facilities/WMD

Robotics will play key roles carrying sensors, drawing fire, serving as shooters (first into buildings, blocking exits and escape), breaching walls and buildings, and clearing obstacles and mines.

Section IV
Analyses and Simulation

Analyses and Simulation

The DSB Summer Study on Tactics and Technology conducted or sponsored several analyses to explore it's expeditionary force concept. The results of three are presented in this section.

- A virtual simulation of the combat cell and it's connectivity to remote sensors and shooters was set up in the IDA Simulation Center. Marines and soldiers were brought in to "play" in the facility.

- A RAND analysis on the value of sensor suites and long range weapons to enable light forces to halt combined arms attacks.

- An Army TRADOC study of a hypothetical future task force employing some of the concepts we are exploring.

Any analysis that could be accomplished on this new, complex, and untested concept during the short course of the summer study must be illustrative rather than definitive. Indeed one of our objectives in initiating these activities was to help jump start the analyses and simulation effort that will be critical to explore and evolve this expeditionary force concept.

The exercises at the Institute for Defense Analyses (IDA) Simulation Center demonstrate the potential of virtual simulations to capture some human dimensions (including command and control options) intrinsic to this disaggregated and distributed concept. We expect that much richer and truer simulated environments relevant to the operation of combat cells and distributed forces can be made available in the near future. The RAND work illustrates the type of analyses that will be necessary to compare the relative worth of alternative sensor, weapon, and other systems options. Lastly, the TRADOC Analysis Center (TRAC) effort provides a rich example of the use of two-sided "campaign" level analyses to explore the strengths and vulnerabilities of new expeditionary force organization, Concept of Operations, tactics, and materiel to perform a variety of missions in different operational environments.

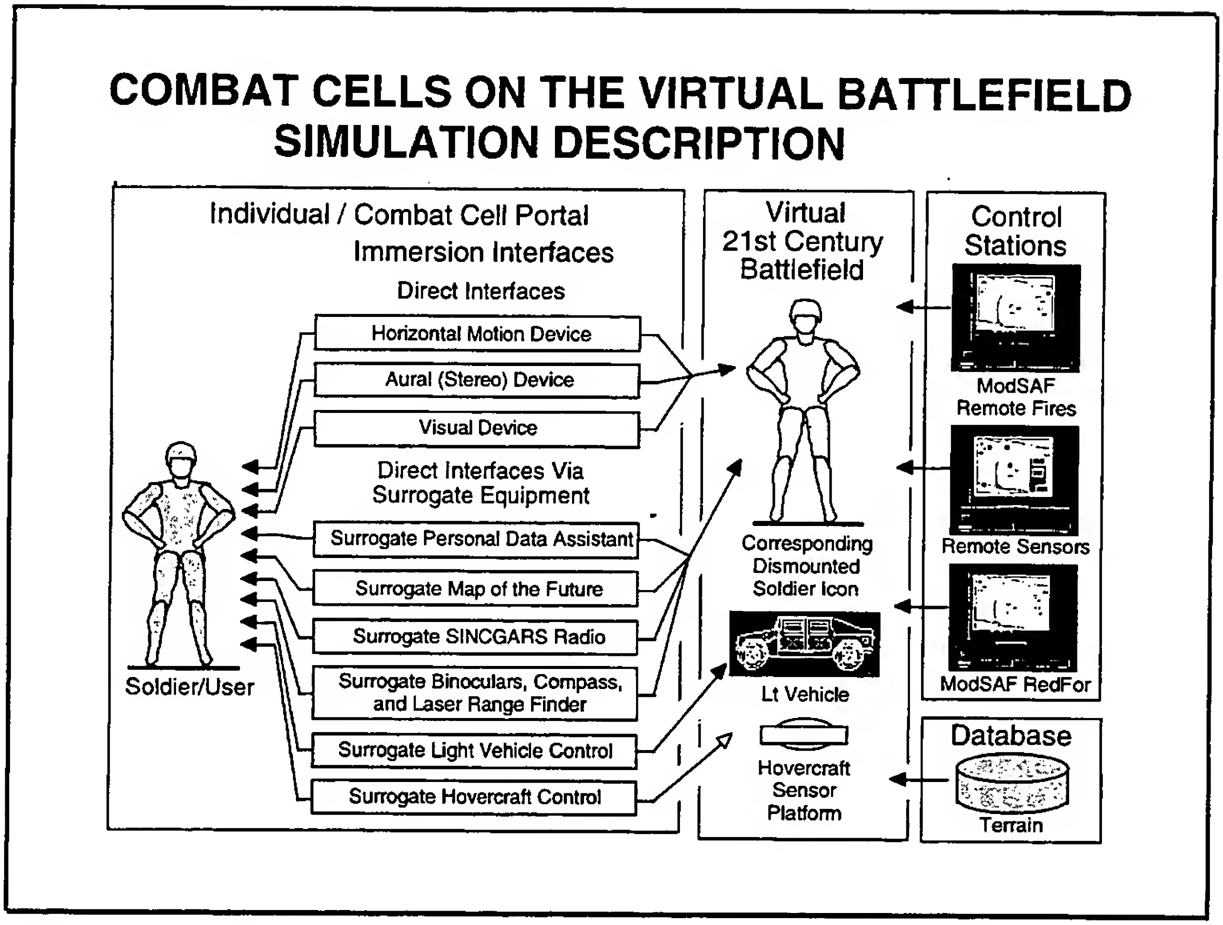
In addition to these three efforts, GAMMA Corporation provided analysis and historical data on relevant small unit operations (a summary is provided in Volume 2, Part 1, Section IV). The Joint Precision Strike Demonstration (JPSD) and Joint Warfighting Center (JWC) were also responsive to our Task Force's call for help and provided results of both new and previous modeling efforts that helped illuminate our problem.

A VIRTUAL REALITY SIMULATION OF THE COMBAT CELL CONCEPT WAS CONDUCTED FOR OUR STUDY

- Effort sponsored by DDR&E and conducted at the IDA Simulation Center
- New simulation capabilities were constructed and exercised during course of our study using existing components and software
- Marines and Army infantry officers experimented with the simulator

More details of The Institute for Defense Analyses effort can be found in Volume 2, Part 1, Section IV.

A follow-on plan has been separately prepared and given to the DDR&E and the Director, DARPA to enhance and continue research, simulator development, and experimentation on combat cell and related distributed force operations.

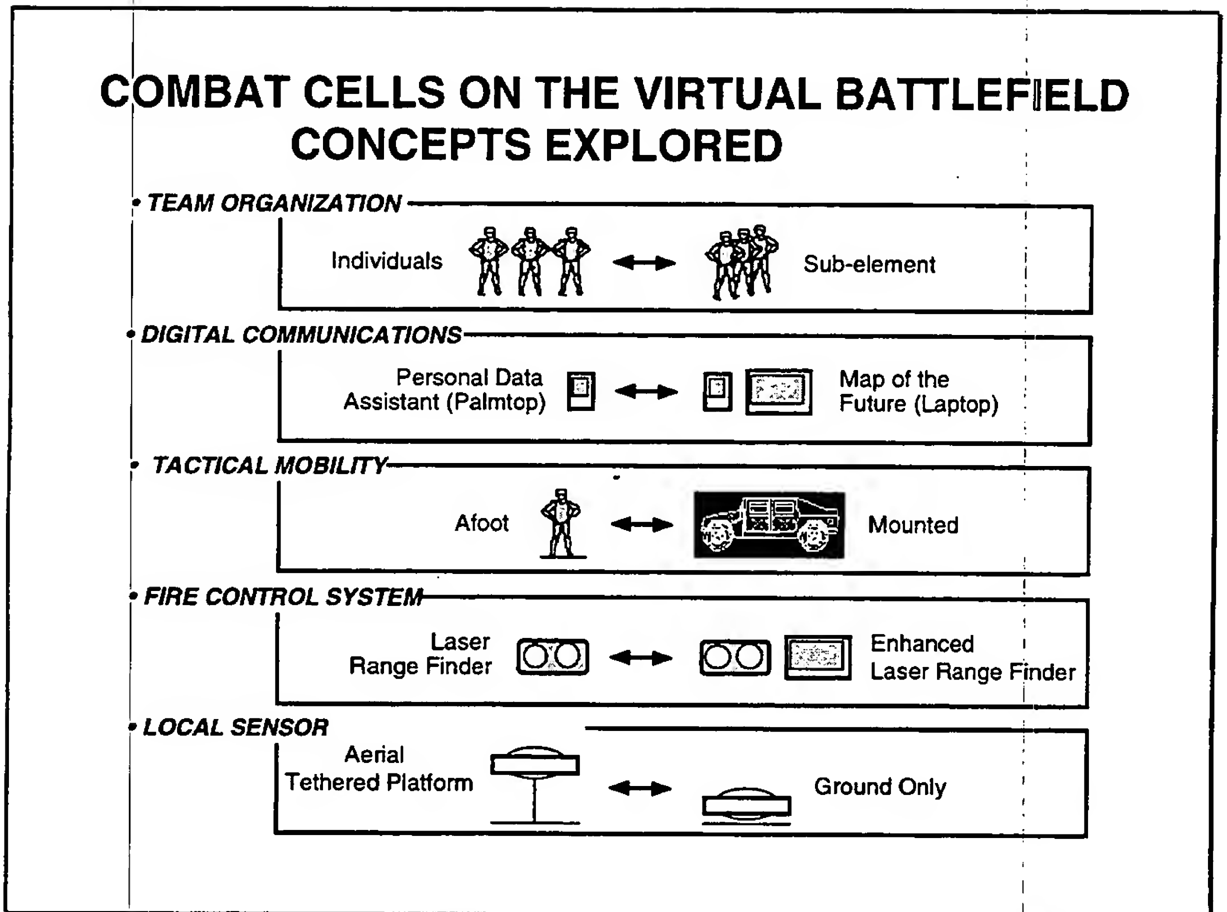


The virtual simulation portrayed the targeting and situation understanding elements of two combat cells, plus higher headquarters. The simulation was used to examine variations in environment, cell composition, and equipment. Army and Marine officers served as the live subjects (players) in these trials. Cells were assigned missions to control an area (size varied up to 5 km radius).

The geophysical aspects of this battlefield were created from digital terrain databases. Two different environments were explored: a desert and a European type with numerous tree lines and rolling hills. Modified synthetic automated forces and adjunct models were employed to provide remote fires and sensors, and enemy forces that included tank, armored vehicle, truck-mounted, and dismounted platoons.

Members of the cell were placed in portals that provided interfaces with the virtual environment and virtual equipment. The individual(s) could walk, run, crawl, see, hear, and talk on the virtual battlefield.

The cells conducted 7 combat operations, ranging in duration from 1 to 3 hours. During these battles the cells received over 200 sensor reports and requested over 150 remote fire missions. Throughout the approximately 14 hours the cells were engaged in combat, they were confronted by about 175 enemy platoons (tank, BMP, truck, or dismounted). The trials were observed by tactical and behavioral experts who monitored and recorded participant activity.



The alternative concepts depicted above were explored during the combat cell virtual battles. These included alternative allocation of tasks among members of the cell as well as equipment options.

For example, the relative effectiveness of a laser range finder (incorporating binoculars and an electronic compass) was compared with a similar device integrated with a data entry device/radio and software which predicted the targets location at the projected time of impact of indirect fire. Alternative fire request and fire control procedures between the cell and the task force headquarters were also explored.

Following each combat operation, each member of the cell filled out a questionnaire and participated in an After Action Review (AAR) together with the observers, subject matter experts, and the software designers. Based on these AARs, cell doctrine was modified and, periodically, the Personal Data Assistant (PDA) and Maps of the Future (MOF) functionality were modified.

COMBAT CELLS ON THE VIRTUAL BATTLEFIELD OBSERVATIONS AND INSIGHTS FROM THE DSB-SPONSORED TRIALS

(All are subject to further analysis)

- **General**
  - Combat effectiveness is strongly dependent on the apportionment of the roles and responsibilities between the cells and task force headquarters.
  - While individual situational awareness should be enhanced, combat power is derived through teamwork.
  - A dismounted combat cell was not nearly as effective as one that had an agile vehicle.
- **Sensor Management**
  - The major functions performed by the cells were to detect and classify enemy forces not observable by other sensor systems and to help determine enemy intent and options.
  - Battle Damage Assessment was not an effective task for the cells.
- **Data Management**
  - Distributed databases and a multicast communications system would enhance situational awareness and C2 by providing the right information when needed.
  - The cells could validate a target and request fires, but the "system" should track and complete the engagement at the most appropriate time.
- **Weapons Management**
  - Cells need confidence in the fire support system. Without feedback, they clog the C2 system with redundant requests for fire and information.
  - If targets are not tagged and tracked, weapons must engage within 2-5 minutes of the fire request, or the predicted target location may no longer be accurate.
  - The cells had difficulty handling more than two targets at the same time.
- **Data Presentation**
  - Palmtop size map displays were much less useful than laptop size.
  - Control of large areas requires digital, scaleable maps of appropriate size that can perform distributed automated battle management and terrain analysis.
  - Three different data entry and display devices were needed to produce a full capability for acquisition and engagement of targets. These capabilities need consolidation into one device, optimized to support the conceptual doctrine.

GENERAL — The combat cell was made responsible for most aspects of requesting and controlling indirect fires; employing organic sensors; determining areas for remote sensor refocus; and battle damage assessment (BDA). These responsibilities overloaded the cell and overall mission would be more successful if some portion of these tasks were handled by the task force headquarters.

Initially, considerable attention was given to empowering the individual combatant, but it was found that more focus should be on empowering the cells. Forming the cells into sub-elements, assigning distinct tasks to each member of a sub-element and equipping each cell with respect to its collective mission was more effective than when each member was assigned a wide range of tasks and the same equipment.

The cell's combat effectiveness was enhanced when it had transportation to move about the battlefield. The dismounted infantrymen could not move fast enough to accomplish some assigned missions and assure their survivability. With many cells widely dispersed, and large areas for each to control, they should be capable of moving rapidly and stealthily in a vehicle that is easily deployable by helicopter.

SENSOR MANAGEMENT — The cells were able to gather and provide unique information including characteristics of enemy targets and intent. Positive identification of dismounted enemy or enemy using civilian-type transport was often possible only by visual means. Further, the exercises illustrated that cells functioned as sensors that were effective where other sensors were not.

The cells could detect targets out to 5 km, with an elevated, tethered video sensor platform, but still had difficulty detecting targets in restrictive terrain beyond 2 km because line of sight was blocked. A taskable tactical UAV (the Lower Tier Bubble) that could look in difficult places from a favorable angle would enhance situational understanding for both the combat cell and task force.

BDA was not an effective mission for cells since it detracted from more effective primary tasks mentioned above. This is especially true if the weapon time-on-target is uncertain (to the cell) and the cell must therefore continue to follow the target for an extended period. The "macro sensor system" should be capable of performing most BDA, with the cells contributing only when the remote sensors are incapable of performing that task.

DATA MANAGEMENT — Items of equipment should be combined and integrated to expedite transmitting information. For example, a remote sensor sighting could automatically slue the hovercraft sensor platform to the location of the sighting, without requiring the operator to scan for the target.

Once the cell has requested fires on a target, the "fire control system" should determine when to strike. The task force commander can make this determination better than the combat cell because of additional resources and information. However, it is also important for the team to know what action is being taken, in order to have confidence that a target is no longer its concern.

WEAPONS MANAGEMENT — The cells occasionally submitted multiple fire requests for the same target because they received no feedback on what action was being taken to track or engage the target. This detracted from their ability to continue locating and validating additional targets.

The concepts employed required the cell to monitor target engagement from start to finish. This was possible if the target could be engaged within 2-5 minutes. However, most engagements that used long range, indirect precision fires required about 20 minutes. Therefore, the cells needed to stop locating and evaluating other targets in order to provide location updates and terminal guidance for previous target requests. The total system should be capable of tagging, tracking, engaging, and conducting BDA without constant attention from the cell.

DATA PRESENTATION — Improvements of display and message formats will permit the cells to have better situation understanding and expedite processing and dissemination of information. It is not sufficient to automate current manual message formats. Software designers should work closely with the equipment developer and user to optimize data presentation.

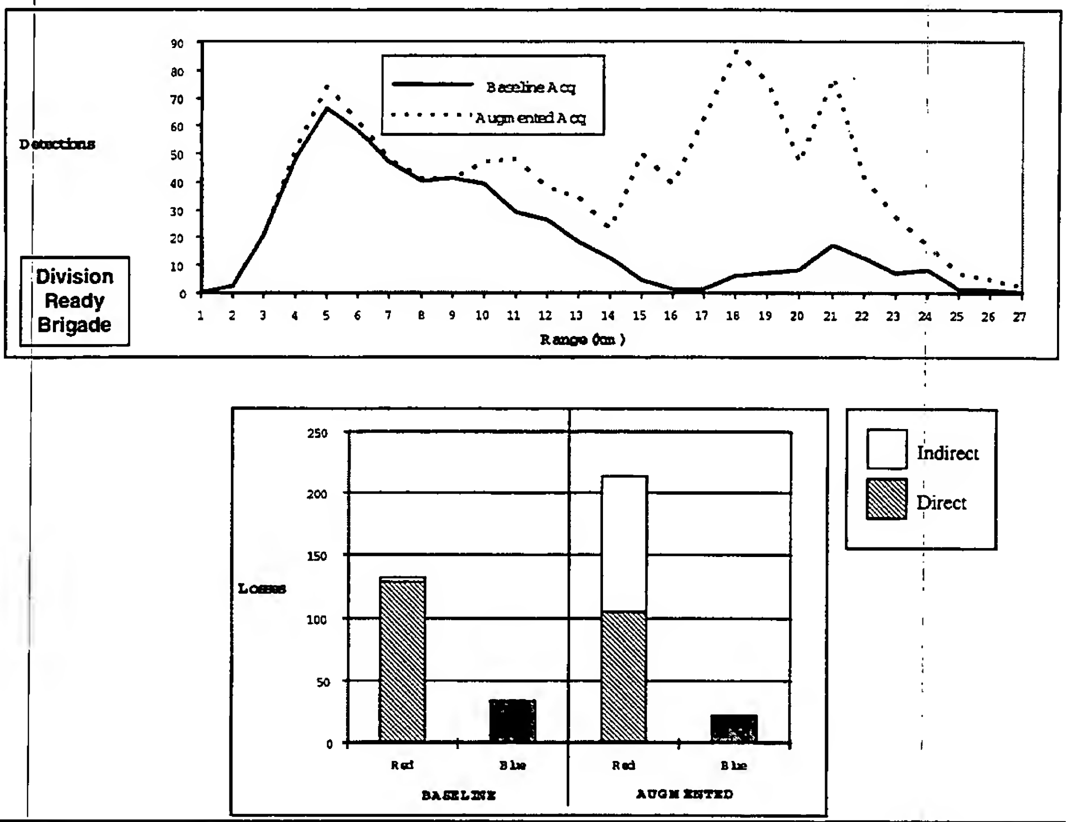
Scaleable Maps of the Future were much more effective than the map on the Personal Data Assistant (PDA) that only presented a small size 3x3 km map. The user of the smaller presentation had difficulty orienting himself on the battlefield and understanding the tactical situation. Digital maps and information manipulated by voice, touch pad, etc., rather than a key pad would facilitate use. A built-in terrain profiling capability would facilitate mission analysis and planning.

RAND Analysis

Analysis work was also performed for the Task Force by RAND to explore the value of alternative sensor and weapon suites to contribute to the ability of a light Blue force to halt/degrade a combined arms attack. The Blue force being used was a division-ready brigade (DRB) modeled after an existing Army unit. The following discussion presents selected results from this RAND Work. The research was sponsored by the Deputy Assistant Secretary for Research and Technology — Chief Scientist in the Office of the Assistant Secretary of the Army for Research, Development, and Acquisition.

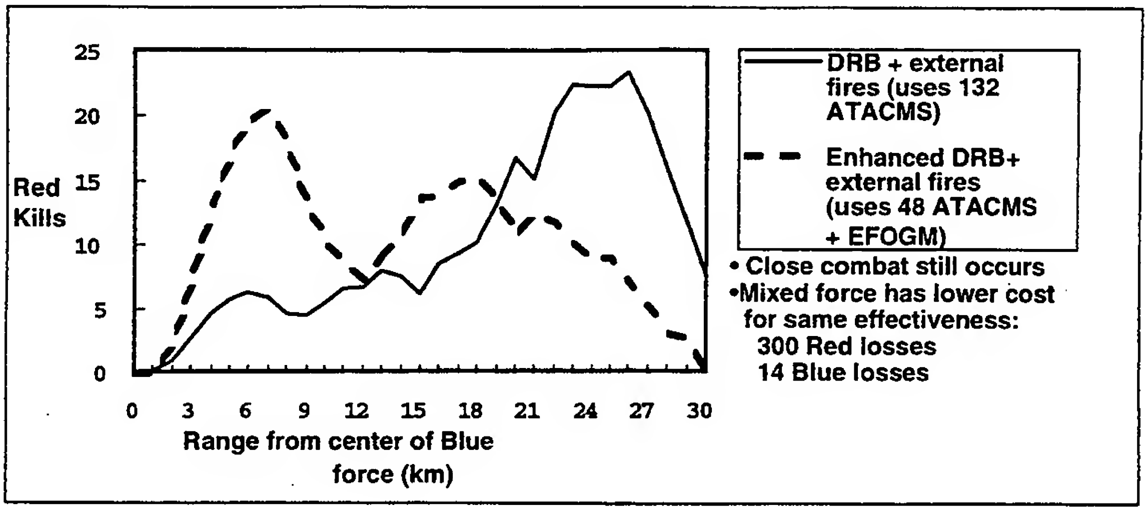
Details of this analysis can be found in Volume 2, Part 1, Section V.

Effects of Long Range Sensors



This chart illustrates results from the RAND analysis of the value of long range sensors in the context of the expeditionary force concept. The difference between the two plots in the upper figure represent the additional detections obtained when an enhanced suite of sensors (UAVs and ground based [manned and unmanned]) is added to the existing sensor suite, organic to the DRB. The RAND analysis show that, when improved sensor systems coupled with longer range weapons (EFOG-M, MLRS, ATACMS, HIMARS/Damocles, 155-SADARM, JSOW, helicopters, fixed wing aircraft, many with submunitions) were made available to the DRB, the combat cell was able to almost double the losses they can inflict while, at the same time, substantially reducing its own losses.

ADVANCED ORGANIC AND EXTERNAL FIRES ARE COMPLEMENTARY—REDUCING COST AND HEDGING AGAINST LEAKERS



An important consideration in the design of the expeditionary force is how much organic firepower will it need in various circumstances. This figure illustrates the type of analysis and tradeoffs needed to understand the options.

Two cases are illustrated in this chart which plot enemy kills as a function of range from the center of the blue forces. The solid plot is the same division-ready brigade (DRB) used in the previous chart, with the augmented sensor ensemble. This force was given as many missiles as it could use as well as tactical air employing SKEET. The preponderance of kills now occur at the longer ranges. Blue is now very effective; the Red to Blue loss ratio increased to more than 20. However, even in this case, with very effective indirect fire, we do not eliminate the close-in battle. Rather, the nature of the close-in battle is changed.

An alternative weapon mix then was used to generate the dashed curve. The number of long range missiles was reduced (132 to 48 ATACMs with BATs) and the force was augmented with an organic capability (in this example analysis, an extended-range FOG-M). Red and Blue losses in this case were nearly identical to the first case, but, the distribution of where the kills occurred changed. Same outcome occurred, but with potentially significant implications for cost and deployability.

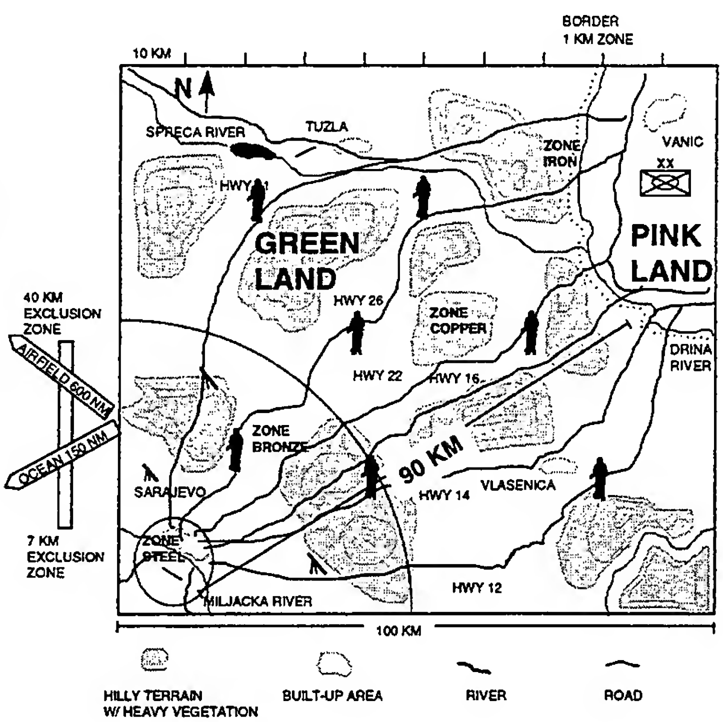
The bottom line of analysis such as this is that there is work to do to investigate effectiveness and cost (including deployment costs) of various indirect (organic and remote) and direct fire weapon systems.

TRAC Analysis

An analytical effort conducted by the Army Training and Doctrine Command (TRADOC) at the TRADOC Analysis Center (TRAC), Ft Leavenworth KS highlights the employment of dispersed combat cells and reliance on indirect fire. The test scenarios encompasses three concurrent and diverse combat tasks: controlling territory in the presence of hostile light infantry, halting a combined arms attack, and operating in urban terrain.

The details of this analysis, called Task Force Griffin, can be found in Volume 2, Part 1, Section V.

SITUATION



RED PARAMILITARY INTENT
- Conduct insurgency operations
- Undermine Greenland's government
- Preclude the arrival of follow-on Blue Forces.

PINK INTENT

Pinkland has positioned forces 40 KM east of the border will attack if they:

a. Suspect stronger Green-Blue diplomatic ties
b. Can exploit continued instability in Greenland

FRIENDLY FORCES
- Greenland has no standing military
- Police force only capable of maintaining order in Sarajevo
- UN has requested Blue take the lead in restoring order. ***Blue deploys Task Force Griffin as the leading element of a JTF***

TRAC analyzed an operation in a fictitious location, although using some of the terrain of Boznia-Herzegovena, with Sarajevo located as indicated and the enemy force being some 90 km away (in "Pinkland"). There is a paramilitary "Red" force operating in the country attempting to undermine the government which has no standing military force. An external, more traditional force in Pinkland is trying to take advantage of the situation and promote instability within Greenland, and is preparing to launch an attack with a combined arms force. The U.S. was requested to come into the country with a task force to assist in providing order and to deter and/or stop a successful Pinkland attack.

TASK FORCE GRIFFIN'S MISSION AND INTENT

Mission

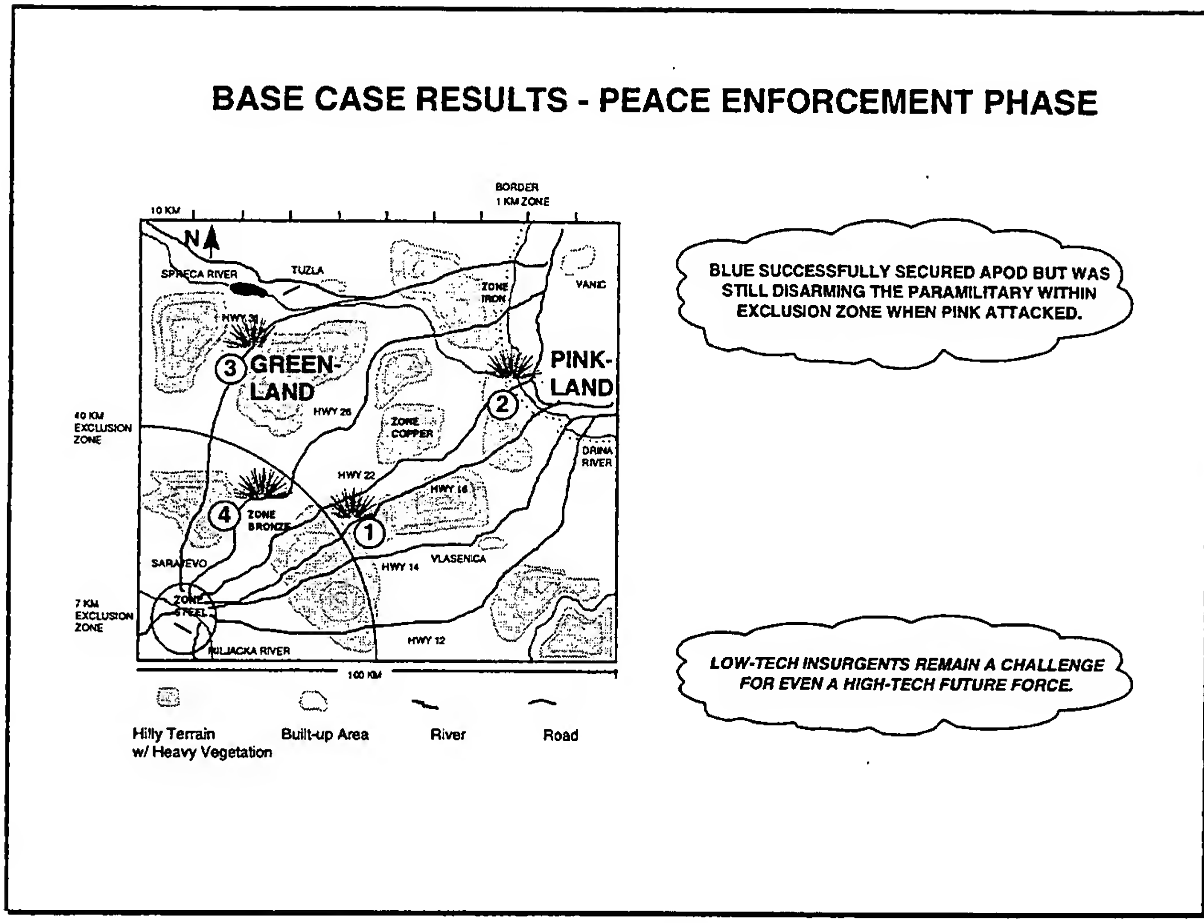
Task Force Griffin secures APOD, disarms the paramilitary forces within the 40 KM exclusion zone, and assists local authorities in restoring order. On order, defeats the Pinkland forces allowing no penetration of the 40 KM exclusion zone.

Commander's Intent

- Initially rapidly deploy Precision Strike Teams (PST) and Aerial Platforms to clear Zone Bronze and seal the border. Assume some risk outside 40 KM zone.
- Survivability of PSTs and supporting elements is a paramount concern.
  - Insure teams have access to indirect fire assets and situational awareness grid. Isolated teams will reposition to reestablish linkages.
  - PSTs will not become engaged in direct fire engagements with heavy conventional forces.
- Success is defined as eliminating threat to airfield, halting Pinkland forces outside 40 KM exclusion zone and setting conditions for follow-on forces.

To address this problem, "Task Force Griffin" — a force that does not exist today — was "created." Its mission is summarized above. It had a number of new systems and employed new tactics including aerial surveillance platforms, lift and attack helicopters, indirect fire systems and, of particular relevance to our study, precision strike units configured to operate in widely dispersed postures. It employed a total of 120 four-man teams, each equipped with a Future Reconnaissance Vehicle (FRV), sensors, some direct fire weapons, and digital data links to provide real-time sensor data to the combat cells.

Some results of the analysis and TRAC's observations are shown in the following three charts.



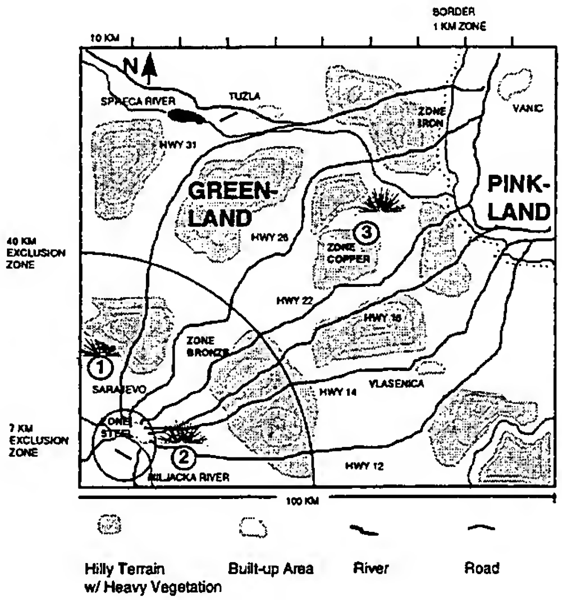
During the Peace Enforcement Phase, Task Force Griffin successfully secured the APOD and had dramatically reduced the insurgent's capability to employ indirect fire assets in Zone Bronze. Throughout this phase the Task Force was, however, vulnerable to the activities of a relatively low tech force.

A humanitarian aid convoy was ambushed in a small built up area by an enemy RPG gunner operating out of a garage and also able to trigger some command detonated mines. These results suggest other possible options to counter low tech threats in this risky mission. These options include the use of conventional forces that can dismount and clear the route more effectively or the employment of some devices that might be able to nullify the ambush.

Primary focus within zone bronze was to eliminate the indirect-fire threat to the airfield that was posed by rockets and artillery.

Supported by strict Rules of Engagement (ROE), Blue successfully employed a combination of UAVs, Precision Strike Teams (PSTs), and helicopters to achieve complete coverage of border and halt red infiltrators. Two helicopters were destroyed by insurgent fired man portable air defense (MANPAD) munitions. While it can be argued that future helicopters will have on-board protective systems to preclude such an attack, it was not assumed, within this study, that rotary-winged aircraft would be able to fly with impunity throughout the area of operations. It was postulated that some relatively inexpensive system would be available even in the year 2015 that could pose a threat to rotary-winged aircraft. Robotic resupply would pose fewer risks.

BASE CASE RESULTS - COMBAT OPERATIONS PHASE



BLUE SUCCESSFULLY HALTED THE PINK-LAND ATTACK AND PREVENTED PINKLAND FROM PENETRATING THE 40 KM ZONE

- Defeated red attacks on the airfield
- Countered cruise missile attacks (Using elevated sensor platforms)

The Red attack on the airfield is defeated, with the conventional forces playing the critical role. These conventional forces, which are appropriately structured for such a security mission, were able to defeat this threat without forcing the PSTs to abandon their overwatch strike missions against the attacking Pink force.

The limit of advance is as depicted. Pink forces “went to ground” 60 KM from Sarajevo once they were reduced to 30 percent strength. The key Blue killers on the battlefield were the long-range precision munitions. Over 60 percent of Pinkland combat vehicles were destroyed by indirect-precision munitions. Interestingly, Blue’s expectation that the enemy would attack along the southern routes proved incorrect. The Pinkland’s main effort, in fact, attacked along Highways 22 and 26 with the supporting effort in the South. The Pink commander assessed that the cover and concealment provided by the northern routes was more beneficial than the high speed avenues of approach provided by the southern routes.

TRAC OFFERED THE FOLLOWING INSIGHTS BASED ON THIS ANALYSIS

- **Organic mobility** allowed the Task Force to avoid direct fire engagements with heavy, conventional forces, insure greater sensor coverage, engage fleeting targets when appropriate & respond to a radical change in enemy intent

- A **mechanism is needed to synchronize sensors and shooters**, optimize sensor employment patterns, insure sensor cross-cueing, facilitate rapid target handover and rapidly fuse intelligence

- The ability to **mass the effects of multiple, dispersed systems** enhanced the effectiveness & survivability of the Task Force

- The **ability to attack throughout the depth of the battlespace**, enabled by a redundant suite of sensors, precision long range munitions and an integrated sensor-shooter platform, allowed TF Griffin to halt a heavy, conventional force

- A **balanced integration of dispersed teams & conventional forces** was necessary to counter insurgent operations, minimize vulnerability to low-tech systems and eject the heavy force

TRAC concluded that in this situation, Task Force Griffin is a capable, early-entry force that successfully denied the enemy his operational objective.

It further observed that it is an effective "tip of the spear" for conventional forces, but:

- Conventional follow-on forces are required to conduct extensive offensive operations, dominate the enemy, sustain battlefield victory, etc.
- The conventional element within Task Force Griffin is necessary for certain missions, to include seizure of the APOD, crowd control, security operations, etc.
- The balance between conventional forces and dispersed teams may vary as the operational situation changes.

Section V
Enabling Elements of Concept: System Architectures

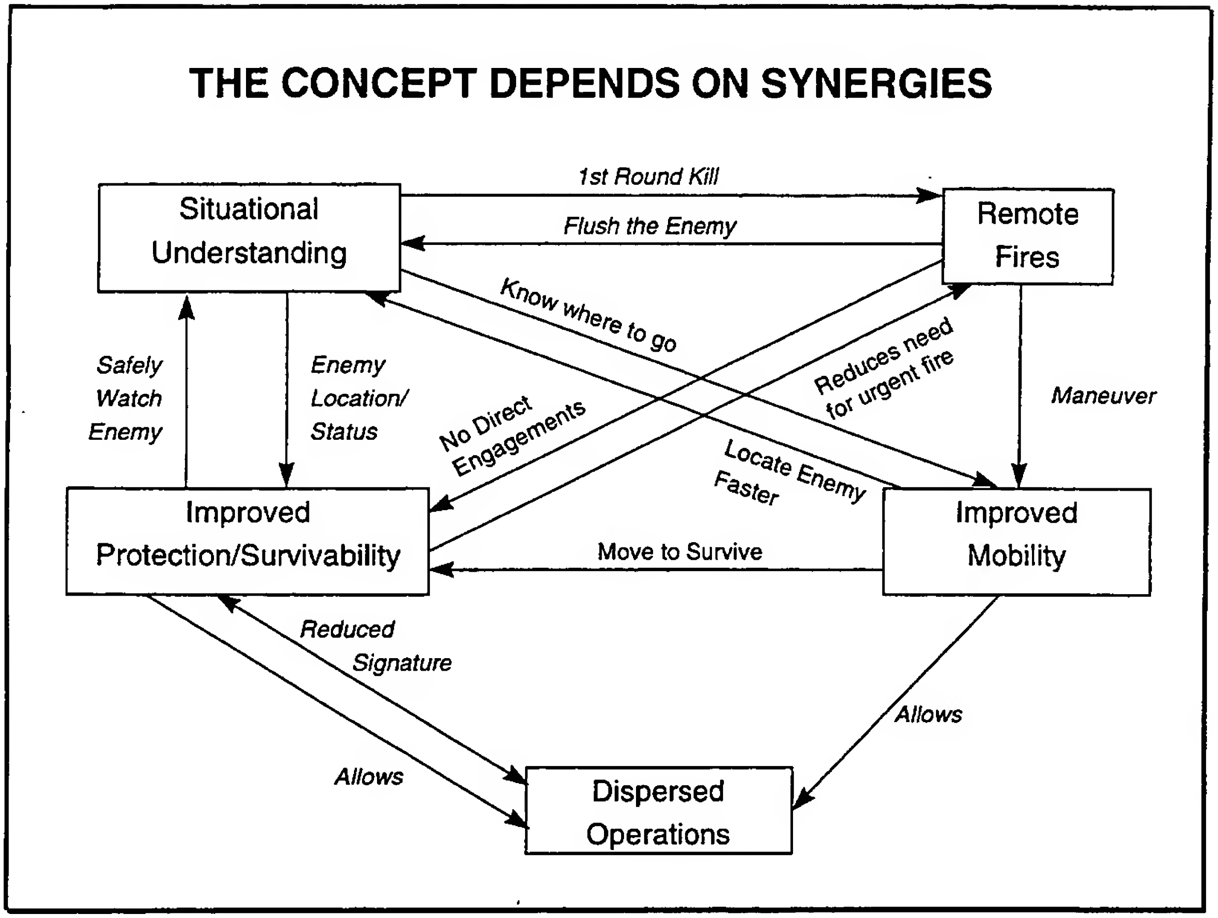
In this section we describe approaches to achieving the critical functions and capabilities identified in chapter II (page II-13) and employed in the CONOPS discussed in Section III.

We begin by highlighting the interdependency of these functions/capabilities and then discuss in order:

- Remote fires
- Battle management, command and control
- Information infrastructure
- Situation understanding
- Ground force survival, insertion and extraction and sustainment
- Training

The section closes by noting some "cultural" obstacles that may impede implementation of the concept.

Additional discussion of these topics is provided in Appendix C of this Volume and in Volumes 2 and 3. For some, (the information infrastructure, situation understanding) we have been able to provide considerable detail; for other (sustainment) our coverage is shallower.



This chart highlights the mutual support among the elements of the overall concept. It suggests the need to develop these building blocks into an integrated whole. If this is done, the overall concept of operations will be more robust and the envelope of scenarios and threats for which the concept works will be expanded. Indeed, exploiting the synergies may make the difference between success or failure in many cases.

The synergies can ease requirements for any one of the elements. For example, the requirements for each of the combat cells organic self-protection are eased by relying on improved mobility (other cells can help out), dispersed operations (which reduces cells signatures), remote fires (also allowing the cell to be lighter and more mobile) and improved situation understanding.

Developing synergistic CONOPS will require doing "experiments" in actual field exercises and in distributed activities where simulations and exercises are melded.

SOURCES OF FIRES

- Organic to the ground force
  - individual and vehicle borne
  - direct and indirect
- Remote
  - Tac Air or ground-based missiles in-theater (if protected)
  - sea-based
  - long range air-based out of theater

Our focus is on the remote fires, to explore the extent to which they can substitute for the ground force's organic fires and thus lighten the force.

There are many reasons, over a wide range of warfighting situations, for employing long-range fires or strikes, including platform/base survivability and the ability to mass fires from dispersed locations. Effective use of remote fires or strikes in support of lightly armed, dispersed ground combat cells will be essential if the cells themselves are to be effective.

Conversely, if remote fires appear ineffective, to the ground combat cells, even initially, they will lose faith in them, will no longer call for them (a well-documented phenomenon), and the whole complex web of synergies among remote fires, maneuver, mobility, and survivability of the cells, on which the cells' operational effectiveness is based, will unravel.

Even in cases in the past when remote/indirect fires have been effective (and effectiveness has varied widely), they have rarely been efficient in terms, say, of total tonnage or number of munitions used to achieve a given effect. In scenarios requiring quick deployment

response (and many important future scenarios are likely to have this requirement), it will be important to minimize total lift tonnage to support the operation. This will mean reducing the lift needed for remote fire support, as well as the lift for the ground combat cells themselves. To do this, the efficiency — the effectiveness to lift ratio — of remote fires will have to be dramatically improved.

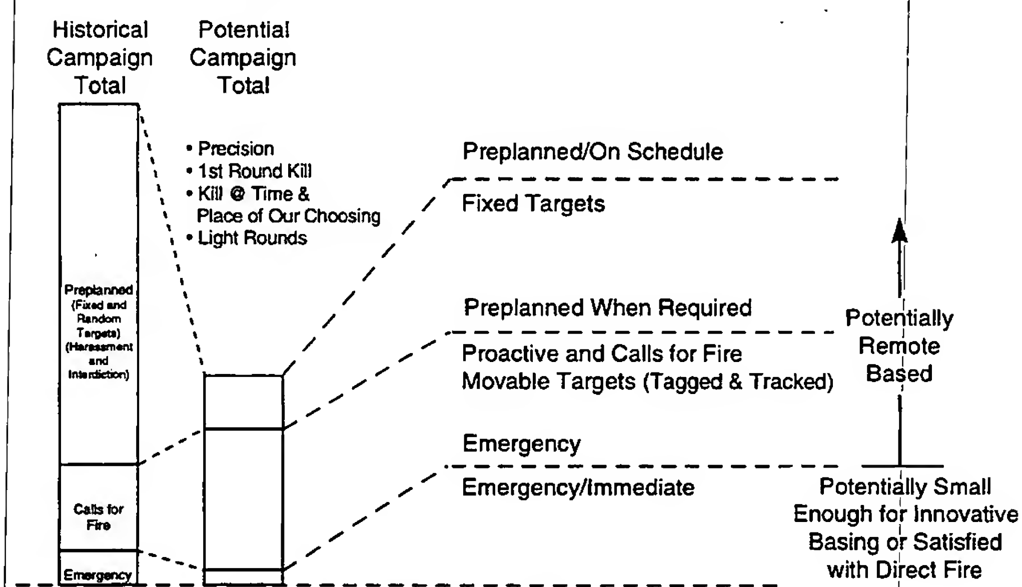
Use of precision weapon systems with enhanced lethality, coupled with vastly improved situation understanding, will be a central means of improving both efficiency and effectiveness of remote fires. Achieving target kill with one or a few rounds instead of many clearly has high leverage. Improvements in situation understanding of the battle or campaign in general, including better understanding of the situations of our own units, will help to allow engagement of only those targets that need to be engaged, <u>when</u> they need to be engaged.

But remote fire in support of the tactical battlefield has also been afflicted in the past with the problem that has often substantially impaired both its effectiveness and efficiency: fleeting targets — that is, targets that are only glimpsed for a short period of time and/or that are mobile. With only short glimpses, it is difficult both (1) to identify the target (is it a small, isolated patrol or part of a larger unit?), and (2) to locate it accurately, especially if it is mobile. If the target moves, of course, the long times-of-flight of remote fires may make them completely ineffective. Vietnam experience from Sting Ray Operations by the Marine Corp (patrol operations behind enemy lines) demonstrated these points. While many enemy were sighted by a patrol, only one enemy was typically killed per patrol, and only one enemy was killed per 15 enemies sighted.

Uncertainty in target identity and location can have a non-linear negative impact on overall effectiveness and efficiency of remote fires. Fleeting targets tend to be treated as urgent targets, and an increase in the number of perceived urgent targets disproportionately complicates fire planning, which in turn, along with other problems, slows the ability to drive the tempo of the battle.

If uncertain and fleeting targets could be "turned into" targets that can be handled as long-response-time targets, many of the problems they cause would be ameliorated. How to accomplish this will be discussed later in the chapter.

PARSING THE INDIRECT FIRE REQUIREMENT: THERE IS POTENTIAL FOR DRAMATIC REBASING



- **Making remote fires work**
  - **More effective fires → fewer rounds**
  - **Less demand for emergency fire**
  - **Ground combatant confidence**

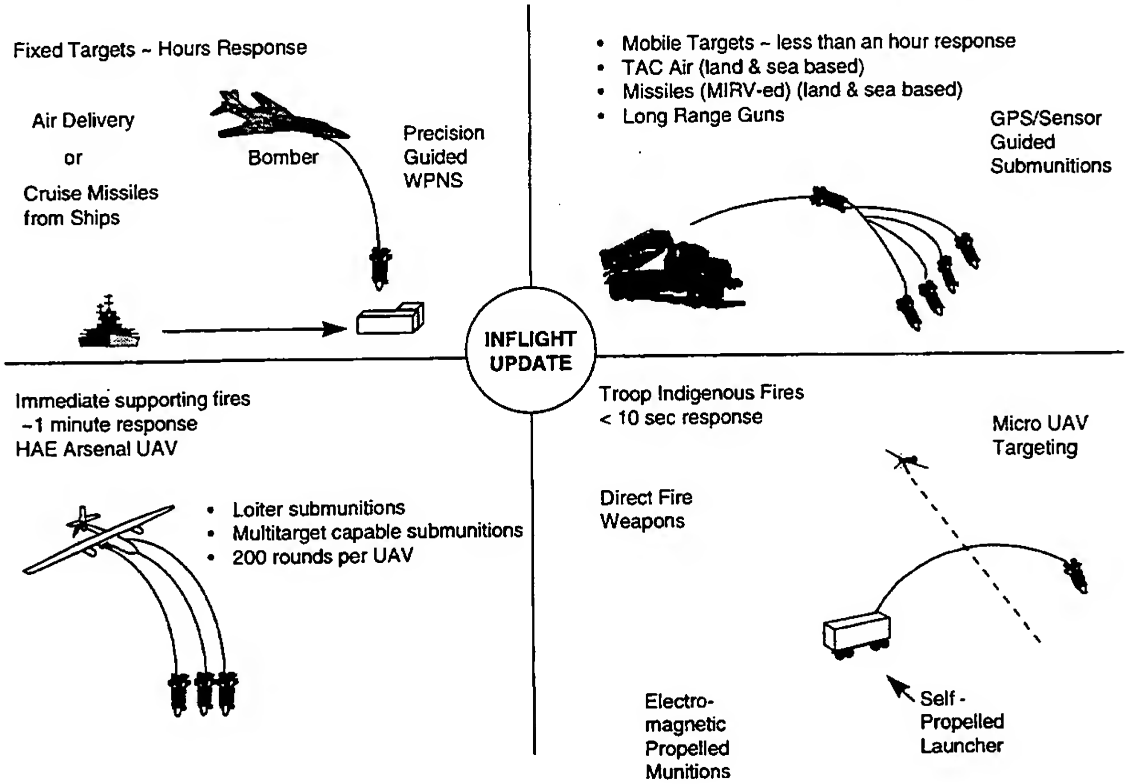
The two columns on the chart are notional representations of campaign indirect fire usage: total amount and allocation by type (preplanned, calls for fire, and emergency calls for fire — fires needed within a few minutes. In past wars, the bulk of fires were often preplanned.

Merely rebasing (i.e., remoting) historical total weights and rates of fires will not be practical. Effective remote fire support of the expeditionary force will require that we do the job with much less mass of fire than the historical norms. Achieving a dramatic increase in the efficiency of fires will depend on exquisite situation understanding, precision weapons and first round kill.

Furthermore, we also need to change the mix of fires. We want to be more effective against moving and movable targets (by tagging and tracking) and to reduce the dependence on emergency fires (through the combinations of means discussed earlier, particularly enhanced situation understanding which helps the combat cells avoid trouble). Emergency fires tend to be expensive, because the weapons need to be either very close or very fast.

Thus, to make remote fires work, they must be more effective (fewer rounds), there must be less demand for emergency fires, and the combat cells must have higher confidence that the remote fires will be available to meet their needs in a timely manner. If we are going to put these people ashore, and we tell them, "Your major fires are coming from afar," they must be confident that fires will really come when they need them. The IDA simulations reconfirmed that repeated calls for fires — and waits of ~20 minutes for those fires — quickly erode confidence.

FIRES REBASING CONCEPTS AND WEAPONS



An ensemble of weapons will be required to support the expeditionary force concept.

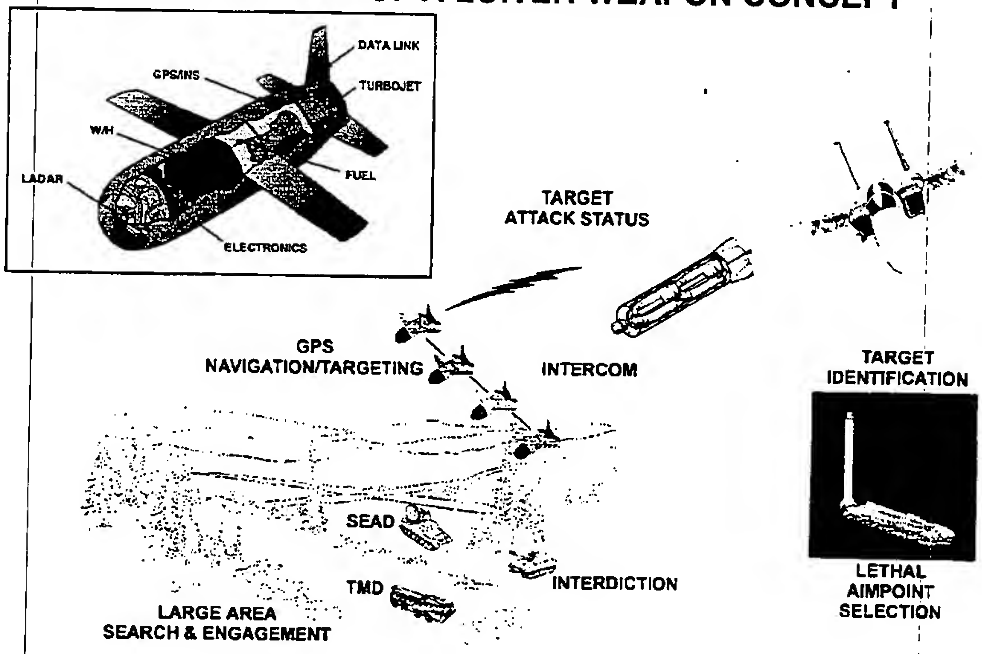
In the upper left quadrant, we have weapons delivered by long-range aircraft (bombers) and sea-based cruise missiles. These systems are typically used against fixed targets and have response times measured in hours. In the future, their target set could be enlarged to also take on some mobile targets by a combination of enhanced situation understanding (including in-flight updates) and loitering capability (inherent in the bombers, can be provided for the cruise missiles).

A second set of weapons/basing is depicted in the upper right quadrant. These weapons have response times much less than an hour. Platforms would include sea-based aircraft, missiles, and long-range guns, and depending on the scenario, could also include tactical aircraft and ground based missiles in-theater.

A loitering concept (lower left quadrant) could meet the need for urgent (~1 minute) fire. We have "invented" a UAV system (e.g., an arsenal UAV) that could carry several hundred rounds.

Finally, a small portion of the fire support could be based with the combat cells themselves to handle situations requiring <10 sec responses (lower right quadrant). The lower right quadrant depicts a notional weapon — a remotely operated, self-propelled launcher with electromagnetic propelled munitions — that could be inserted along with the cells themselves.

AN EXAMPLE OF A LOITER WEAPON CONCEPT



Over the past five years, the U.S. Air Force and Army, have been sponsoring the development of a smart submunition called Low Cost Autonomous Attack System (LOCAAS). The LOCAAS is designed to loiter and autonomously hunt for targets, report what if finds, and then kill the highest priority target. It can be delivered by aircraft, rocket, or missiles.

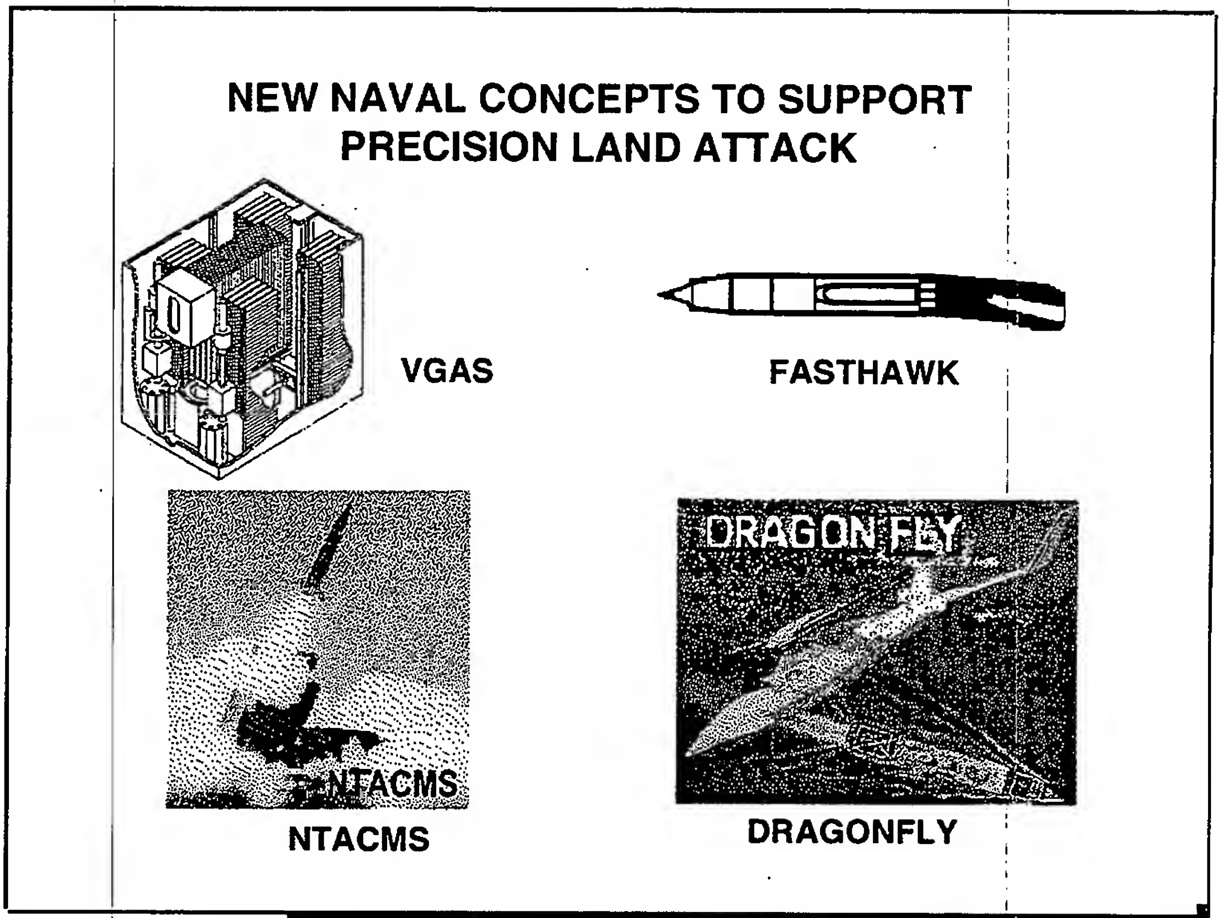
After dispensed by its delivery system, the vehicle wings/fins are deployed and the engine is started. The GPS/INS system navigates the munition to the search area. The vehicle descends below the cloud layer and begins to search with it's LADAR seeker. Potential targets are located and either attacked immediately (depending on assigned priority) or stored for possible later attack. Many potential separate target types can be stored in its onboard memory and additional targets can be added in the field. Just before warhead detonation, an attack status message is sent back to the shooter via data link. Other munitions in the vicinity monitor transmissions so that multiple attacks will be avoided, and if they do not find a target they can find and attack a target passed over by another reporting munition. We can easily envision this type of weapons being designed to also be responsive to targeting information generated by the combat cells.

The glide version was successfully flight tested during in 1994 and a newer powered version is capable of 30 minutes of flight. The vehicle navigates with Global Positioning

System (GPS) and a low cost Inertial Navigation System (INS). A data link is employed to relay information collected by the submunition and its actions back to the shooter.

The submunition is designed carry a multi-mode, explosively-formed-penetrator warhead. When detonated, it will form either a long rod penetrator, an aero-stable slug, or fragments. The target aimpoint and warhead mode are automatically selected by the weapon's automatic target recognition (ATR) algorithms associated with the onboard laser radar (LADAR) imaging sensor. This combination of an imaging sensor and multi-mode warhead will allow the submunition itself to tailor its lethality against different targets (hard and soft).

Powered LOCAAS is currently in development and is scheduled to begin flight testing in 1996.



Effective sea-based fires are essential if the new expeditionary force concept is to be a robust in a variety of situations, but the absence of almost any such fire support is a major deficiency today. The Navy is devoting more attention to this area and exploring several weapon concepts, although most are still in preliminary stages. Three of these are shown above (an extended range guided munition for the Mark 45 five-inch deck gun is in a more advanced state of development.) Also shown is a concept for a marinized UAV to provide surveillance, targeting, BDA communications relay, and other critical C[4]ISR functions.

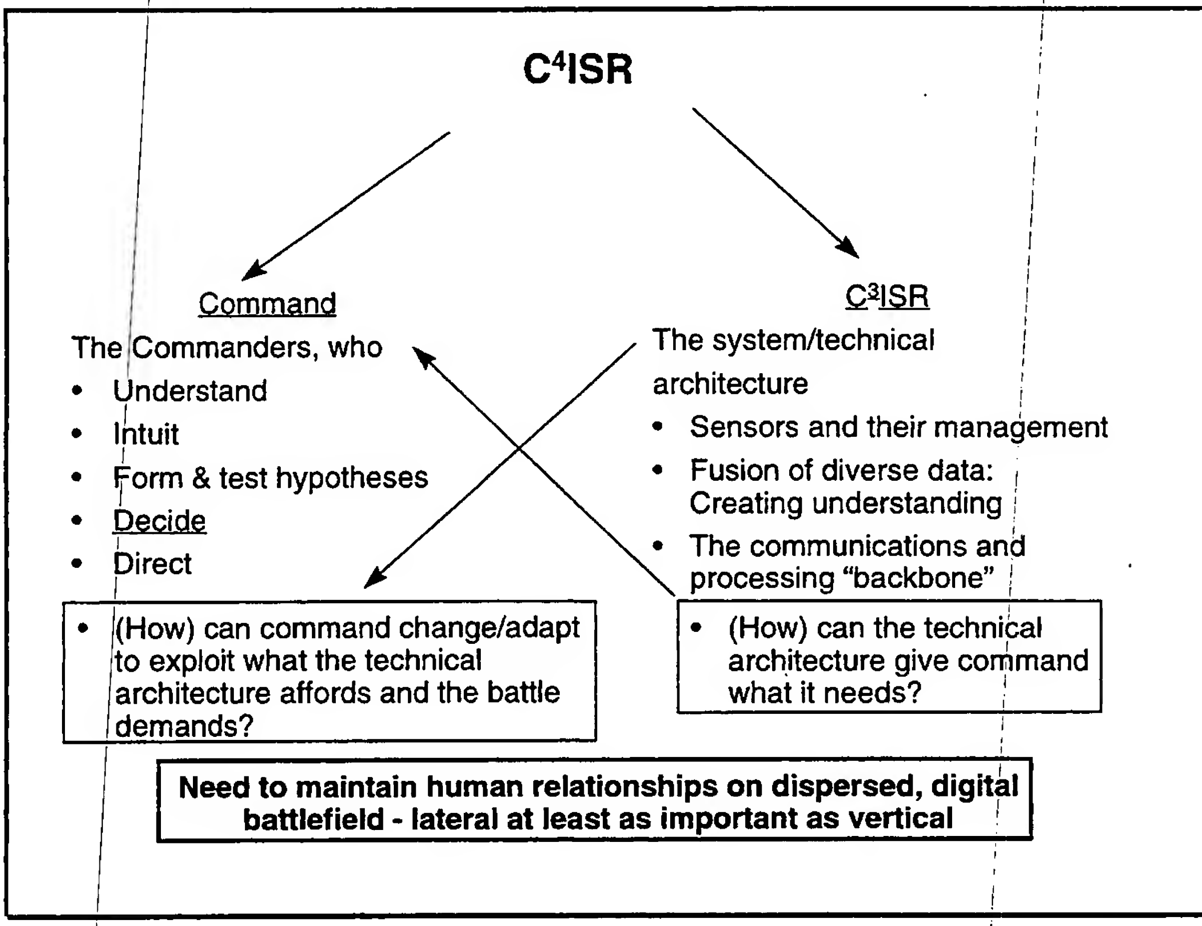
A particularly interesting new weapon concept to support the expeditionary force is the vertical launched, 155mm, automatic loading, rapid fire 155mm gun. With internal propulsion, ranges of 200nm may be feasible as is a capability to loiter. An ability to reload at sea (more difficult for missiles) is an important benefit. The gun could be carried on many ships; e.g., each gun would replace four VLS tubes on an Aegis Cruiser or Arleigh Burke destroyer. If the cost per effective precision round can be kept reasonably low, then the several hundred million dollar estimated development cost for the gun may be a high payoff investment.

The Arsenal ship, being explored in a joint DARPA and the Navy effort, could support the expeditionary force concept. However, we caution that merely adding a few thousand more

VLS tubes to the approximately 10,000 tubes expected to be in the fleet by 2003, will not by itself contribute to the concept unless new weapons that can effectively attack ground targets are developed, deployed, and connected to robust (joint) surveillance, targeting, and battle management systems.

From the perspective of our expeditionary force concept, we suggest that investments in enhanced joint C^3ISR for land attack and new sea-based weapons compatible with existing platforms (including submarines) would have higher payoff than investing in new platforms. A fire support capability distributed among numerous ships, each capable of receiving munitions at sea, could offer important advantages with respect to survivability, availability and flexibility. (We recognize that the Arsenal Ship has missions and objectives other than those we considered in this study.)

Battle Management, Command and Control



Command, Control, Communications, Computing, Intelligence, Surveillance, and Reconnaissance (C4ISR) is much talked about in general, but the term obscures the important distinction between *command and control*, which (at all levels) are an essentially *human* function involving the things listed on the left in the chart, and the more *technical* activities in "C3ISR" on the right of the chart. (Of course human judgment and skill make the technical systems work.)

In the two boxes below command and C3ISR, this chart poses the two questions which must be addressed to weld together the human function of command with the design and operations of the technical system architecture. But it is important to concentrate, first, on what command is, and what the commander does, in the new circumstances. This is developed on the next few pages.

As S.L.A. Marshall so well articulates in Men Against Fire, combat is about humans and human relationships. As the battlefield becomes more digitized, the systems more automated, and — especially — as battle becomes more dispersed (a centuries-old trend), an overriding requirement on both the commander and the technical architecture is to maintain, and strengthen, human relationships, mutual support and the mutual understanding on which it is based, laterally and in both directions in the command structure.

TWO FACTORS INFLUENCING FUTURE COMMAND RELATIONSHIPS

A. Enhanced Situational Understanding Means: (For Example)

	Higher Commander	Lower Commander (Local)
Big Picture	Understands (his) big picture much better	*Can understand the higher commander's big picture*
Local Situation	*Knows much better which locations are most important and can understand any local situation (almost) as well as any local commander*	Understands his local situation much better. Understands his peers'/buddies' situation much better

B. And weapons/sensors can (technically) be controlled by anyone from dispersed locations

Good decision making, which is at the heart of command, requires congruence between knowledge (understanding) and authority. In the history of warfare, the intersection of understanding and authority was aligned with the command hierarchy — the higher commander understood the larger picture better than his subordinate, and made large-scale decisions; the subordinate knew the local situation better and made more detailed/local decisions. Indeed, this paralleling of understanding and authority is what defines the hierarchy of command.

Vastly improved situation understanding, as posited for the future, can make traditional hierarchical decision-making work even better (as in the upper-left and lower-right of "A" above). But it can also open up new possibilities orthogonal to the traditional proportionality between understanding and authority, as shown in the lower-left and upper-right of the figure. This flattening of effective access to, and use of, knowledge/understanding, combined with the future technical ability to control weapons or sensors (or maneuver) from almost anywhere (at least in principle), offers the potential for a flattening of command relationships, as illustrated on the following page.

The theater commander *can*, with his resources available and with his situational understanding capabilities, focus on critical dispersed cell events and anticipate their

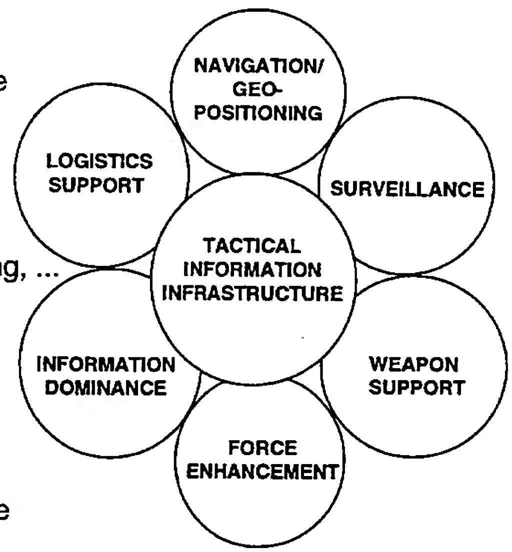
needs and proactively allocate forces to them. The theater commander can also delegate authority to a cell leader, for example to directly control the theater's long-range sensors or directly employ the theater's arsenal UAV for a specified period of time.

We believe that future technology *enables*, and future battle *demands*, a wider and more diverse set of command relationships. As illustrated above, the technology will enable both greater centralization and greater empowerment. Learning how to make best use of these additional degrees of freedom and develop appropriate command structures will require the interactive prototyping of both innovative command relationships and the supporting system/technical C[4]ISR architecture.

Information Infrastructure

INFORMATION INFRASTRUCTURE: SUMMARY OF LEADING EDGE STRIKE FORCE NEEDS

- Tailored information, when and where required
  - Information rather than data
- Support any organizational structure or size
  - Scalable, flexible, reconfigurable
- Comprehensive information services
  - Terrain, pos/nav, situation understanding, ...
- Reliable, inexpensive, available
  - leverages commercial technology
- Personal information ensemble
  - Light weight, long life, small, easy to use



The information infrastructure must provide tailored information services to diverse users from a single person to a collection of people, sensors, and/or weapons by means of intelligent agents — software entities under the general control of the user, which are goal directed, migratory, able to create other software entities and provide services or functions on behalf of the user.

The information infrastructure must include multimedia data transport, including land-line, radio, and space-based elements. All of these media must be integrated into a ubiquitous, store-and-forward, data internetwork that dynamically routes information from source(s) to destination(s), in a way that is transparent to the user. This data transport segment of the infrastructure must be self-managed, adaptive to node or link failure, and provide services to its users based on quality-of-service requests. These services include bandwidths, latency, reliability, precedence, services (point to point, point to multi-point), and the like.

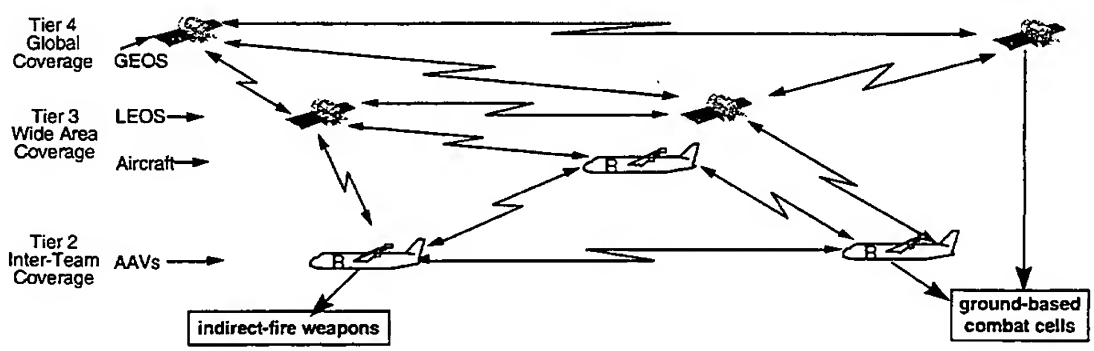
The infrastructure interface will link the user to a distributed processing environment which includes all types of computers situated at locations commensurate with their needs for power, environment, and space. This distributed computing environment will be integrated via the data-transport element of the infrastructure, thus enabling these processors to exchange data dynamically, share computation loads, and cooperatively process information on behalf of and transparent to the user.

Within the infrastructure, each user is served by intelligent software agents that proactively provide and disseminate appropriately packaged information, including such functions as fusing and filtering information, and delivering the right information to the right user at the right time. Proactive in this sense means that the software agents are aware of the user's situation and needs, and can provide information relevant to those needs without a specific user request.

Because computing resources are distributed throughout the infrastructure, the infrastructure can adjust the amount of processing resources given to a force entity. The entities' processor need only: provide access to the infrastructure, provide an adequate interface to the user entity, and enable the acquisition and present information to the user. Thus, for example, a dismounted infantry person's information ensemble would be dedicated to supporting a rich human-computer interface (with voice recognition, heads-up display, speech synthesis, and communications). General computing resources would reside within the infrastructure itself.

To the maximum extent feasible, the infrastructure transport components take advantage of commercial technology and networks, by utilizing open-systems standards and protocols, and minimize the use of service or function-unique hardware and software. For applications where military-unique functions, such as anti-jam, low probability of intercept, spectrum utilization, etc., are required, military products will be developed or adapted to interface with the overall architecture.

INFORMATION INFRASTRUCTURE: AREA AND GLOBAL TRANSPORT



- Multi-tiered Information Transport
  - Autonomous Airborne Vehicle (AAVs) provide coverage to combat cells
  - AAVs are cross-linked to provide dynamic, store-and-forward services
  - AAVs position themselves to provide robust, fail-safe interconnectivity
  - AAVs crosslinked to LEO/GEO for global resources (indirect fires, sensors)

This chart shows a warfighter's view of the tactical information infrastructure. In operational terms, this infrastructure comprises local-area networks that provide services to entities on the ground. These transport networks are all store-and-forward, packet-switched data systems that are self managed and adaptive, and provide peer-to-peer data relaying and processing. These networks adapt to changes in the locations (i.e., the mobility) of its end users; they have no centralized nodes or base stations that would enforce the use of a vulnerable star topology; and they automatically route information amongst the nodes (based on real-time assessments of the network connectivity). These local-area networks can support a single person or a force structure of any size (through appropriate subnetting).

Air- and space-borne networks and processors provide data transport and information services among force entities that do not have connectivity on the ground. An ensemble of autonomous air vehicles (AAV's) provide medium-area networking services. These platforms are cross linked between themselves and the space-borne network, and are linked to the local-area networks. The routers*, depicted as [R] in the figure, understand the entire system's topology and connectivity in real time. In conjunction with the intelligent software agents, the routers make dynamic routing decisions based on this understanding, to ensure that information is transported from all sources to all destinations, as required and at any point in time.

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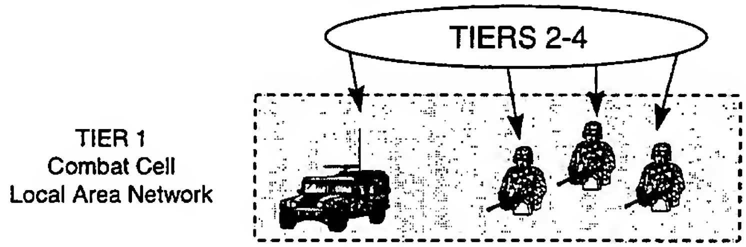
* Routers are currently used in the commercial internetwork.

INFORMATION INFRASTRUCTURE: WARFIGHTER'S PERSONAL INFORMATION ENSEMBLE

- To support unit cohesion within small, distributed cells: a need to be satisfied



- Integrated processing and communication resources
- Based on commercial cellular and digital assistant technologies
- A "networked" device; supports integrated multimode services - Paging, Conferencing, Imaging
- Integrated POS/NAV Function; precise time; terrain; enemy & teammate positions
- Supports quality of service requests (e.g., bandwidth on demand)
- Supports multimodal interfaces (e.g., voice recognition, heads-up display)
- Integrated into the Tactical Information Infrastructure

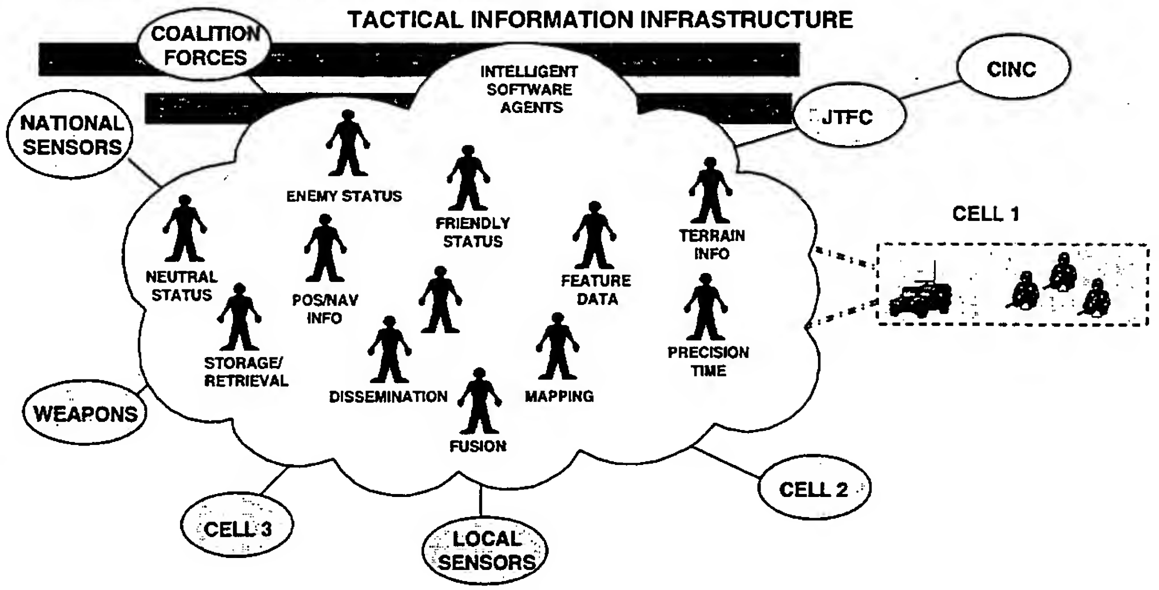
WARFIGHTERS PORTAL INTO TII

The warfighter connects to the broader information infrastructure through a personal information ensemble that is based on commercial cellular and digital assistant technologies. This ensemble provides integrated mulimode and multiband services, position and navigation, precise timing and pertinent, tailored situation awareness through commands to, and reports from, intelligent software agents. Warfighter interaction with the personal communications ensemble is interactive, voice and video based, hands-free and does not require computer or database expertise.

The personal communication ensemble is fully integrated with personal protective and other standard military equipment, and offers anti-jam and security features.

The protocols and algorithms developed for the warfighter's personal communication ensemble will provide numerous services to the user. Examples of these services are multicast and broadcast information reception and distribution, conferencing facilities, network time (absolute and relative to a cell), and real-time reporting of a cell's geolocation and logistics status.

INFORMATION INFRASTRUCTURE: INTELLIGENT SOFTWARE AGENTS



- Intelligent Software Agents:
  - Relieve Cell Members of Information Management Functions
  - Provide Data Fusion, Information Storage, Retrieval and Dissemination
  - Tailor information at the right time, to the combat cells needing it
  - Allow users to request information in mission specific terms
  - Provide geospatial and time information services

The infrastructure is an intelligent network. Each component exchanges state information with each other, in order to enable the entire infrastructure to adapt to user requirements and any stresses imposed on the network by an adversary. This adaptability also enables the infrastructure to change its scale as necessary to support force structure(s) of arbitrary size, or to incorporate new processing, network, and communication technologies as they are developed. Thus, this infrastructure is a scaleable computing environment.

Within the infrastructure, each user is served by intelligent software agents that proactively provide and disseminate appropriately packaged information, including such functions as fusing and filtering information, and delivering the right information to the right user at the right time. Proactive in this sense means that the software agents are aware of the user's situation and needs, and can provide information relevant to those needs without a specific user request. This chart provides a conceptual rendering of these agents.

These agents multiply the personnel resources available to the combat cells by gathering and transforming data into actionable information to support cell operations, just as cell members would have to, were the software agents not provided. Cell members are therefore freed of routine chores in favor of actual operations.

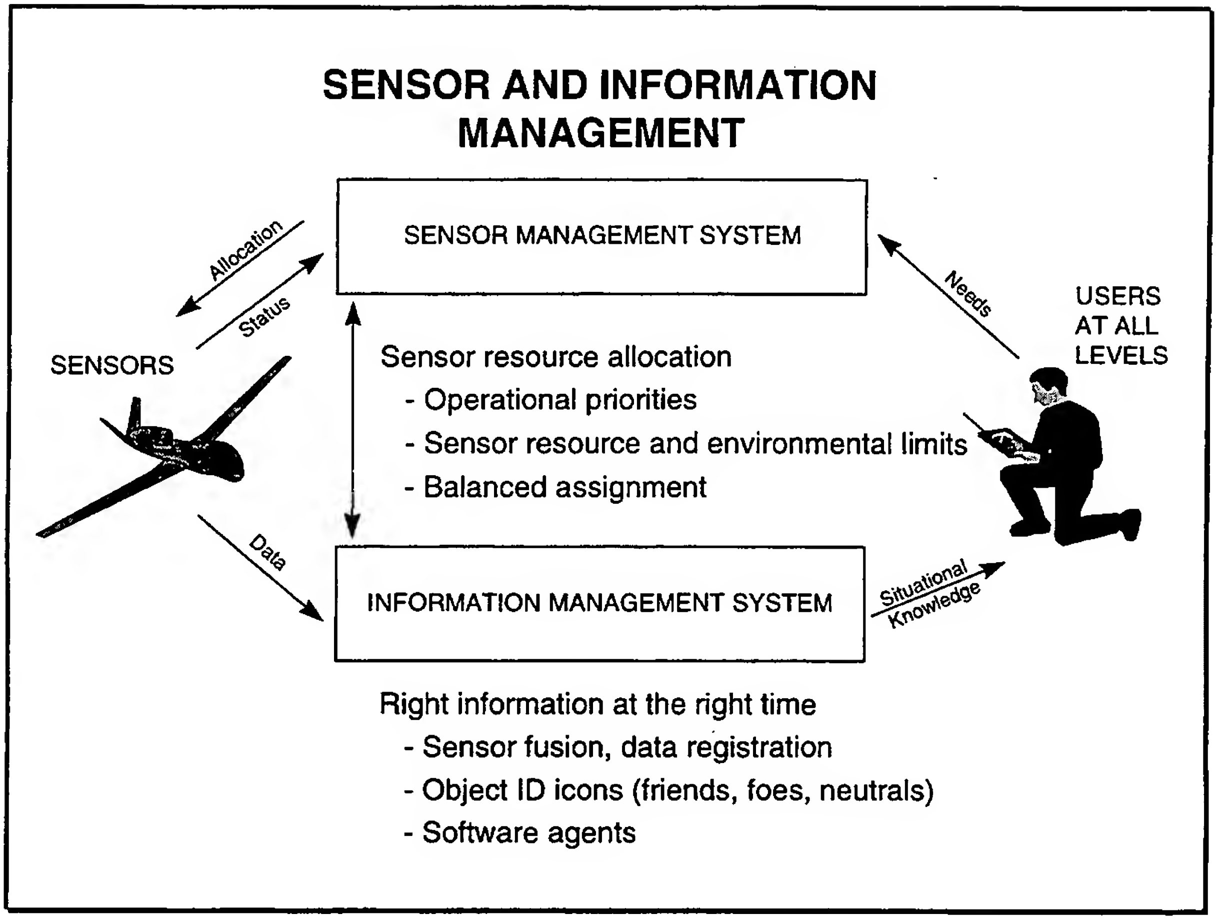
RISTA VISION

Turn fleeting observations, "blobology" into:

- Shared, comprehensive, composite fire control quality picture of battle ground – do for the ground battle what CEC is doing for the fleet air defense
- Composite picture developed from
  - Multiple platform sensors, views, phenomenology
  - Tagging
  - Context analysis
- Sensor & information management becoming critical battlefield task

The two major challenges in the information arena are:

- a sensor management system that can dynamically manage the sensors, and
- an information management system that can move the data to the right place and the right time, and fuse information properly.



The ability to understand what is happening in their environment over a larger area of coverage and at a level of fidelity well beyond current capabilities is critical to the success of the distributed combat cells. This truly "exquisite" situational understanding can enable cell members to detect and monitor enemy activities well before being detected themselves, and therefore gives them the decided advantage of choosing their time for action, be it engaging the enemy with remote fires, hiding while continuing to monitor enemy activity, or moving to a safer or more advantageous vantage point.

A realistic vision of a 20-year future has the soldier and marine in the field able to see, using a simple heads-up or arm mounted display, a complete picture in his normal field of view that includes objects hidden or obscured by terrain, fog and smoke, trees, and structures. Even more compelling in this vision is his ability to have a *virtual presence in the battlefield*: to see and hear beyond his direct field of view, to look and listen behind the mountain, in the forest, up the road, on the other side of the building, or across town and to participate as a moving observer in the scene. At higher echelons in the theater, the appropriate commanders will be able to simultaneously view the enemy and the combat cells to anticipate problems that each cell may not yet be aware of and provide warning. In short, every user will be able to call up anything that he may need and be able to view it in a clearly intuitive fashion. In this environment, enemy actions and intent will become less

ambiguous, and our own actions precise and timely with high probabilities of mission success and combatant survivability.

The suite of sensors that will emerge will be capable of generating immense quantities of data. To have any significant impact beyond where current evolutionary paths are likely to lead, sensor and information management will have to evolve to an unprecedented type of integration hand-in-hand with the development of the sensor elements themselves.

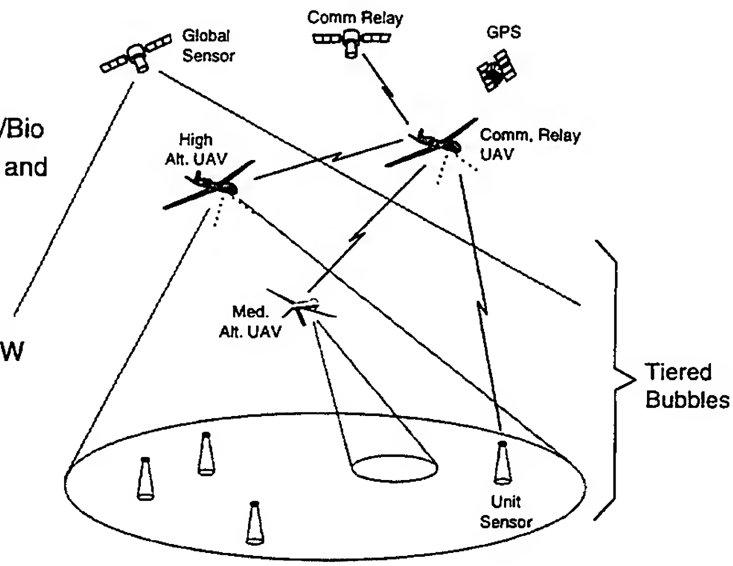
Allocation of the sensor system resources will need to be controlled by a distributed, adaptive, intelligent sensor management system that uses assessments of the status of the sensors, the needs and priorities of the users, and the status of the information currently available to task the sensor network. In parallel, data from the multiple sensors will have to be merged, correlated, and fused by information management systems that can provide "3-D" views of the battlefield. This will facilitate *navigating the battle space* and seeing any portion of the battlefield from any perspective. The added audio inputs from ground sensors should allow all echelons not only to see over the hill or into the forest, but to have a *virtual presence* there.

The advent of distributed intelligent sensor control strategies embodied in intelligent software agents should make realization of these management functions ubiquitous throughout the information infrastructure in place of current architectures that tend to embody the processing functions at a single, and therefore, highly vulnerable node.

SITUATIONAL UNDERSTANDING
SENSOR SYSTEM ARCHITECTURE

Features

- Layered and Integrated
- "All-Seeing"
  - All Weather, FOPEN, Chem/Bio
- Intelligent, Adaptive Information and Sensor Management
- Direct Information to Users
- Terrain Features
- Weather
- Electromagnetic Environment: IW



The sensor capability available twenty years from now will come from multiple platforms (space, UAV, manned air, ship, and ground) with overlapping sensor coverages and resolutions that exploit multiple phenomenologies (radar, EO/IR, laser, acoustic/seismic, biological, chemical, medical, etc.), as illustrated above. Global and regional assets will be integrated with local sensors directly under combat cell control, and possibly seekers on in-flight weapons, to produce an "all seeing" ability for the warfighter (all weather, with foliage penetration and chemical/biological weapons detection capabilities). The system will have the communications capabilities to provide data for processing in real time for users. Data will be position registered and processed to find, identify, and track targets; characterize impending threats to the cell; keep track of combat cell and remote supply status; and, in general, maintain cell and theater situational understanding across much greater areas than the enemy is able to. A major challenge will be ensuring the survivability of such system.

The current rapid growth of sensor technology will continue throughout the next two decades leading to sensor systems with capabilities far beyond today's. Evolution of high density focal planes, MMICS, computing and signal processing, miniature lasers, advanced materials, acoustical systems, miniaturized electronics, micro-machines, etc., will merge into highly capable sensor systems. These systems will be multi-functional, robust, and

compatible with smaller platforms and at costs that allow massive proliferation in the field to cover large areas with unprecedented precision and help provide total system survivability.

By the early part of the next decade, the radars carried on manned and unmanned aircraft will be multi-mode, allowing multiple frequencies and different waveforms (e.g., MTI and SAR) in a single radar system. There will be high frequency radars for target identification and tracking, and low frequency radars with stepped frequencies for foliage penetration and dismounted soldier detection. EO systems will have large focal plane arrays with embedded filters to produce multi-spectral and hyperspectral data. Lasers will evolve to allow ranging, designation, and three dimensional imaging of targets with compact systems, as well as chemical and biochemical characterization of the environment.

On the ground, more sensing capability will be embedded in smaller, low cost unmanned ground sensors (UGS). These UGS will be able to feel, hear, see, interpret, and tag (physically, electronically, and/or acoustically). Communication and intelligence will be added to allow UGS to operate as a smart adaptive local network and interface to the larger information infrastructure. Given that a program is established to develop UGS technology and systems, these sensors will become sufficiently small and affordable to allow large numbers to be deployed, either air dropped or hand emplaced, with the option of sensor and/or platform mobility to allow adaptation to the local environment (e.g., move to get a better view).

OBJECTIVE: <u>UNDERSTANDING</u> THE SITUATION(S)

- Situation understanding is far more than situation awareness
  - Situation awareness is largely sensor derived object locations with identification
  - Awareness: "What", Understanding = "Why" (e.g., enemy intent)
- "Knowledge" is the additive elements of:
  - Reasoning
  - Experience
  - Intangibles
  - Context
  - Intuition
  - Training
- Understanding is a function of Awareness + Knowledge

- May be nearing a threshold: Further improved awareness implies a dramatic, non-linear increase in understanding

The objective is not just to be aware, but to *understand* what is happening on the battlefield. Awareness may confer an advantage on the battlefield, but it is understanding that would give *dominance*.

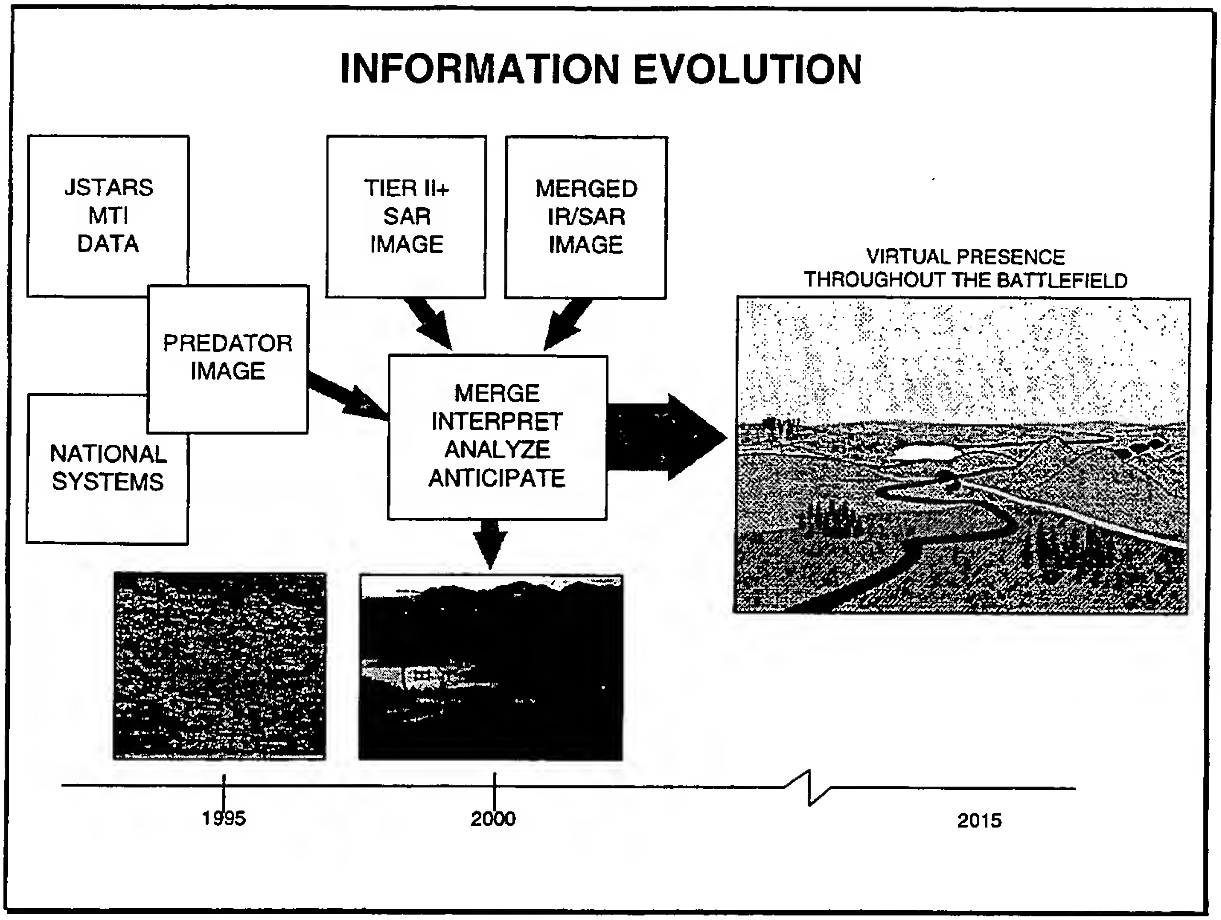
Awareness has to do with mere facts — the *"what"* of the situation. Understanding is a complex human function that includes *why* the acts are as they are. To awareness, understanding adds the elements mentioned above. Understanding can be developed from facts, in part, by forming and testing hypotheses, and by comparing the current situation with similar situations encountered before.

There is usually a strongly non-linear relationship between awareness and understanding. Awareness of only a few facts may create little or no understanding; but at some point, as awareness increases, the underlying "pattern" may become clear, and … "aha"!

It may be that, in a usefully wide range of battlefield situations, improved information technology is bringing us close to that threshold beyond which understanding happens. In developing information technology for warfare and in applying that technology in actual warfighting operations, it is important to be sensitive to the distinctions between awareness and understanding, and to what is needed to cross it is by forming and testing

hypotheses. The information system must be designed to enable the warfighter to do so, and the warfighter must be trained in how to use information in this way.

We will never be able to fully dispel the fog of war, especially with adversaries actively trying to keep us uncertain. But concentrating on understanding as the objective, rather than mere awareness, will build a more proactive, engaged, creative approach to using the information that will be available to us. That aggressive mindset, in turn, will be what really makes the difference. War is about people, not computers, and only a human can understand. Focusing on understanding is the way to make information technology really relevant to warfare.



The success of the distributed cell concept is critically dependent on high quality, robust situational information. This information is needed at many levels: NCA, regional CINC, JTF, the combat cells, and the individuals in each cell. As technology is developed in the sensor, signal, data processing, and networking areas, the completeness and quality of the information available will improve with time.

The Joint Situation Awareness System in used today in Bosnia is a first step toward the type of sensor management we envision. It provides the JTF with a merged picture of the sensor system status fields of view and processed data displayed as icons. With the proper focus and funding, this capability will evolve to provide true fusion of data, over the horizon viewing, object velocities and time projections, and the beginnings of a three dimensional representation of the battlefield. The JTF will know the status and location of each of its small combat cells and use the cell-supplied data to decide when and where to call for fire.

Early in the next decade, this information will be available to the cell commander and individual cell members in an arm- or head-mounted display that provides the needed information in a clear, easy to understand form. The broad area sensors (space, surveillance aircraft, UAVs) will be supplemented by cell controlled sensors (UGS and mini

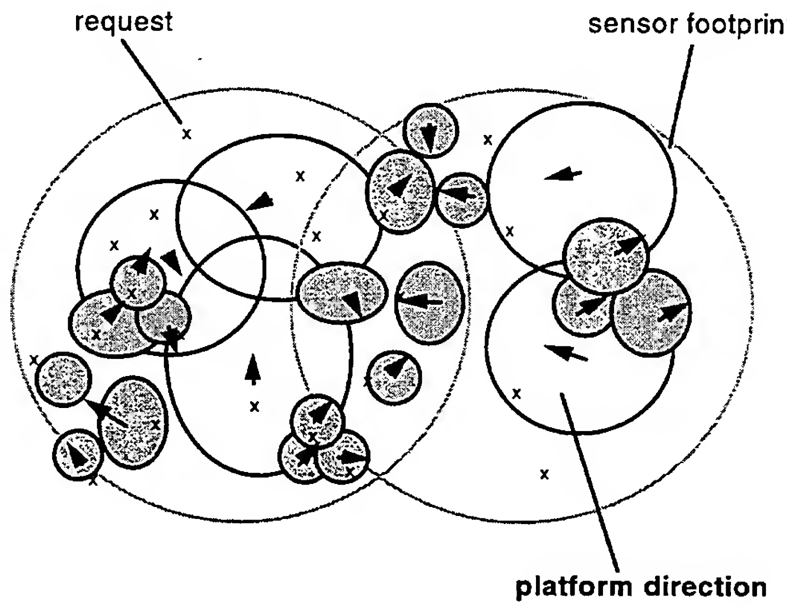
UAVs) to generate integrated scenes. The processing for this fused data scene with object icons will be done throughout the information infrastructure. This merged data will allow the cells to "see" out to the limits of their control areas and beyond. The cell sensor data will also be available at the JTF and higher levels.

The information environment in which the warfighter operates by 2015 will be both physical and virtual; i.e., he will be able to actively participate with events or can view them remotely at his discretion, so the information tailoring process must therefore be under his direct control. His immediate surroundings will be sensed by local sensors that can observe both him and the area of his immediate concern. More global information will be available either from larger area coverage systems or can be obtained through access to historical databases.

This information can then be combined through processing capabilities that the warfighter accesses transparently (with him, the cell, and/or through the information infrastructure) to form a rich composite of the battlefield information that he can navigate through using simple intuitive commands. This information is presented in his personal display registered to his normal vantage point. For example, by combining sensor data from multiple viewpoints (say from other cell members or remote sensors), the warfighter can effectively "see through" obstructions or foliage. If he wishes to "travel" to other locales within the battlespace to view the situation form alternate vantage points, he can do so. He will be able to navigate the battlefield in three dimensions, zoom in on scenes of interest, and view targets as a virtual observer from any perspective.

RESPONSIVE SENSOR SYSTEM

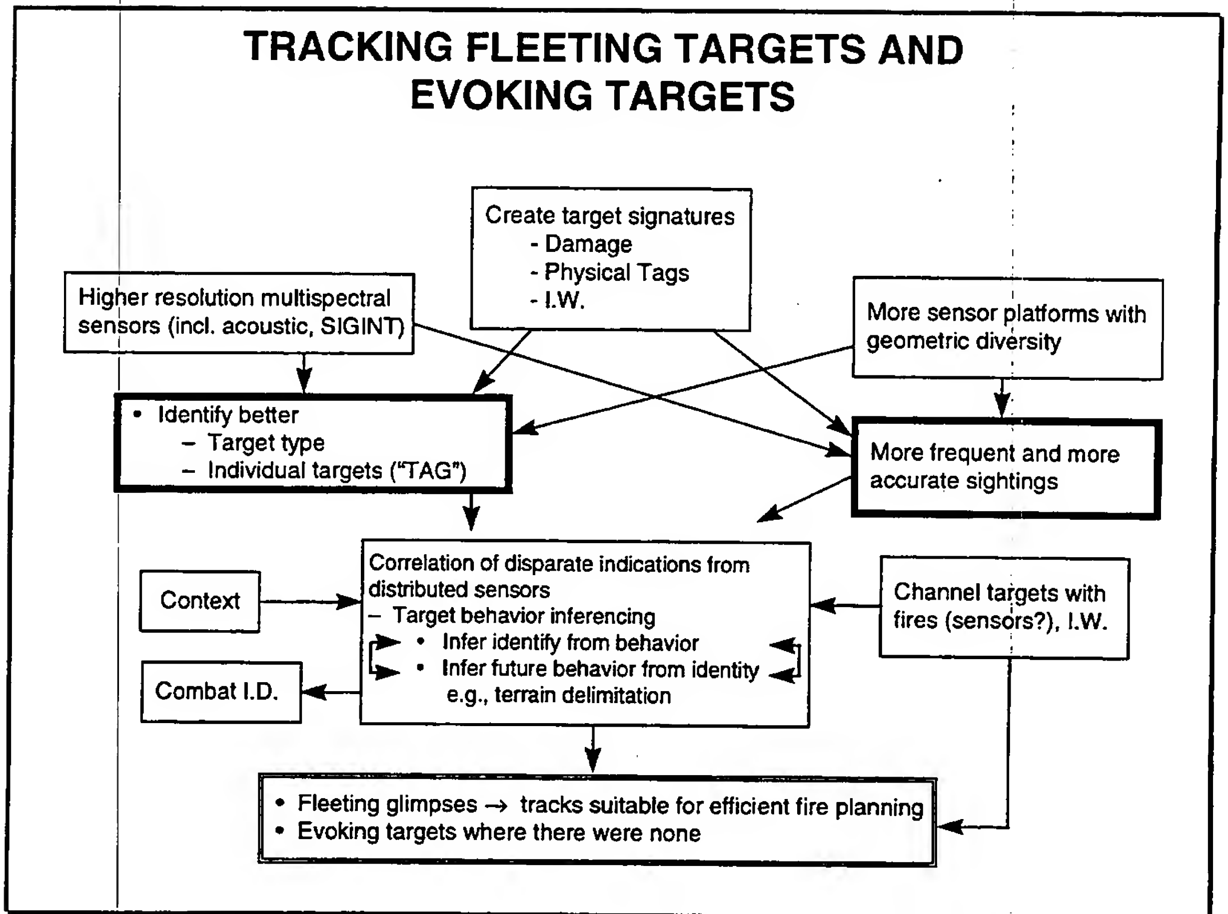
- Multiple overlapping and moving sensor footprints
- Sensor w/ the "best shot" collects the information
- Platform paths are responsive to projected request densities



The sensor management function directs the sensors to collect the information requested by the warfighters at all echelons. It operates to balance assignments among competing requests based on mission objectives and operational priorities and is implemented through a dynamic global optimization process, constrained by the limits on sensor resources and capabilities at each assignment update.

The figure above offers an example of a distribute sensor management approach. The direction of sensor coverage is determined by an internetted self-optimizing allocation process. Each separate sensor platform is attempting to maximize its utility by altering its path and footprint to satisfy requests, in keeping with mission and operational priorities. The process begins with the individual warfighters posting their sensing requests on the inter-sensor network. Each sensor will access the network and observe the density of sensing requests on the ground below it. The sensor will assess its ability to respond to current requests and projections of future ones. The assessments are communicated among the individual platforms and the sensor that is best positioned to collect the information will act accordingly. The JTF will maintain an override option where conflict resolution or new priorities can be interjected.

The results of the collection are placed on the network for direct access by the warfighters and/or further processing by the information management system, depending on the nature of each request. Sensor management could also be carried out with a more centralized approach at the JTF level. Either distributed or centralized — or hybrid — schemes can work. The key, however, is to develop and test allocation algorithms with multiple sensor types and in real situational environments, with sensor glitches and communication dropouts to assure system robustness.



Turning uncertain and fleeting observations into targets that can be handled as long-response-time targets will require a combination of the following:

- High resolution, multi-spectral, multi-phenomenological sensors (including, for example, acoustic and SIGINT);
- More sensor platforms, with geometric diversity;
- Deliberate creation of target signatures and exploitation of signatures inadvertently created by combat; and,
- Smart correlation of all of the above, including inferencing from the combat situation and terrain.

To understand how these might work together, consider first that it may be possible to improve the certainty of identification by inferencing from the object's behavior (e.g., a tank behaves differently from a missile TEL), and, in turn, to improve knowledge of current and future location by inferencing from the identify of the object/target. Supported by methods already under development (such as "terrain delimitation," in which knowledge of terrain is used to determine where a tank, say, *can* go within a given time from the last sighting) and by improved understanding of how the battle is going (which could hint at where a target's commander might *want* it to go), this iteration between improving identity- and location-certainty could converge. Also, a skilled commander might be able to channel movement of an opponent's assets by how he applies fire (or sensors), which could also improve knowledge of both identity and location.

This fusion/integration and inferencing function would be greatly enhanced by improved sensors and CONOPS for their management. Target identity has two elements: (1) what *type* of target (tank or truck, or what type of tank); and (2) what individual object (*which* tank)?. With high enough sensor resolution, and by observing several different types of signatures (acoustic, optical at various bands, electromagnetic emissions, etc.), it may become possible to "fingerprint" individual land combat objects/targets as is routinely done today for radars and submarines, for example.

Target identification could also be enhanced by exploiting signatures created in battle. For example, a tank that has sustained partial damage from an anti-armor munition may have a unique infrared signature, or a unit that has taken losses may behave differently from an intact unit. Also, in some cases, it might be possible to affix an actual, unique physical signature to the target — a "bar code," so to speak. (For example, for other applications, a special paint has been developed which dries into a pattern whose details vary from splotch to splotch, creating a unique signature.) It may also be possible to use IW methods to do this.

By such means, an individual object or target might be "tagged" (i.e., assigned a unique identifier), which would allow correlation among separate sightings and greatly aid the inferencing methods mentioned above.

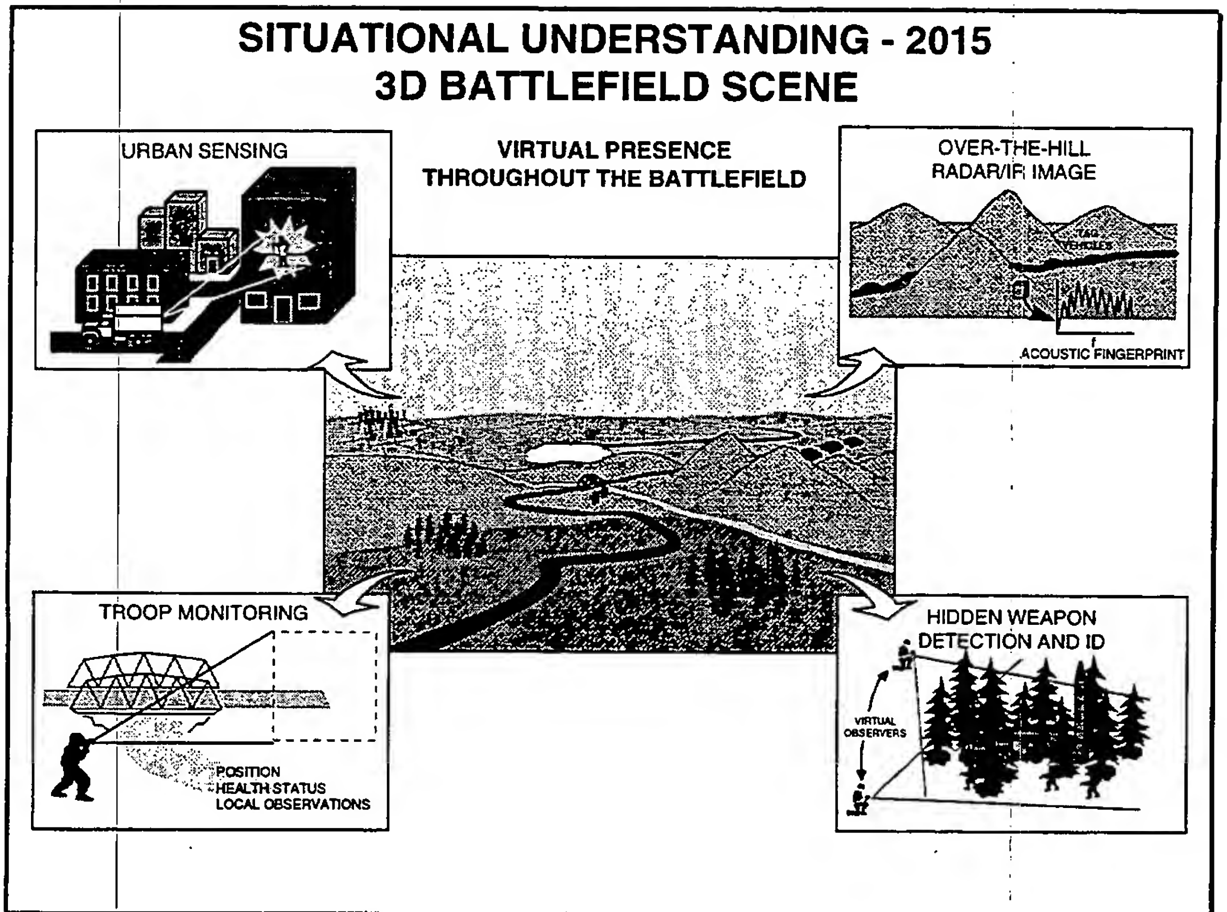
Deploying more sensors in more locations (unattended ground sensors, sensors on UAVs, using the combat cell as forward observers, etc.) can both produce more sightings to give a more fine-grained (or even continuous) track, and increase location accuracy.

How all of these things fit together is shown schematically in the preceding figure. In sum, the objective is to be able to identify an object well enough and to sufficiently narrow the range of predictions of its likely future location so that it can be handled in an orderly way — prioritized in value and vulnerability, and ordered in time — either for targeting or for sensor revisit. If this can be done, then in many cases, long-response-time fires may suffice.

Of course there will still be targets that are urgent because they are immediately threatening. The methods invoked here, along with better understanding of our own units' situations, can help us to understand which targets are immediately threatening and cannot be evaded. For those, quick response will be needed, including weapon platforms which can loiter over the battlefield (armed UAVs, for example) and immediate fires from threatened units or their neighbors.

The capabilities discussed here can "evoke" targets, too — that is, discover targets that would not otherwise have been seen, further adding to overall effectiveness. And note that another beneficial outcome of all this will be improved combat identification.

All of the pieces of the approach sketched above are already in varying degrees of development. Making them all work together will be complicated, in part because simulation and/or exercises involving battlefield operations will be essential. The flip side of the complexity is the opportunity for synergy, which can add robustness and reduce the need for any single part/aspect to work perfectly. At some point, to begin to exploit potential synergy, one or more ACTDs will be needed, followed by fielding of prototype capability and then refinement of it.



By 2015, sensors will be able to provide 1 foot to inches or better resolution data over a broad frequency range, from several platforms with multiple perspectives. Foliage penetration sensors will be able to detect and identify targets hidden within forests. Active sensors will remotely detect chemical and biological agents and micro point sensors will identify the agents. Each cell will have a mini unmanned VTOL and micro UAVs with EO and radar sensors for detecting vehicles and people out to ranges of 20-30 km, queued by UGS, that will initially tag and track the targets. The data from the various sensors will be merged, and position registered to allow navigation of the battlefield and virtual presence anywhere in the observed or nearby terrain (in foliage, over hills).

Urban terrain presents unique challenges for sensor, navigation, and communication systems. Here the need to see through and around structures — to produce a "virtual line-of-sight" — is critical. As such, there will be much more dependence on cell controlled sensor systems (UGS, robots, micro UAVs).

The warfighter environment is not solely image-based. Data for other sensor domains (SIGINT, acoustic, etc.) is included and combined for display. Objects within the environment that have distinctive signatures are labeled automatically (ATR and SEI type process) and placed in the warfighter's local database. Once in the database, they can be

manipulated through voice or intuitive icon command. The object manipulations include simple annotation and suppression, but more importantly, interrogation. The warfighter can query the symbol in the database for supporting evidence (e.g., acoustic signature), history (e.g., how many times has this radio been on before?), and relationships (e.g., what enemy unit is this tank from?).

Examples of the type of information that might be available are shown in the above figure. The cell members will know where each member of the cell is located. The cell commander will have access to the location and health status of each cell member and each member's local observations (lower left). Using UGS and foliage penetrating sensors, hidden targets will be found and identified (lower right). If the foliage is too dense for remote sensors to image or the targets are in shelters or caves, UGS, forward observers, and micro UAVs can be used in concert to identify the targets. Targets hidden by terrain can be viewed by a complex of sensors, tracked, imaged, and acoustically or electronically tagged by UGS (upper left and right).

CELL SURVIVABILITY IN FUTURE OPERATIONS: DESIRED ATTRIBUTES

- Dominant situational understanding
- Infiltration/extraction capabilities that minimize enemy detections
- Extensive use of IW and deception
- Stealth at unit and individual level, e.g.
  - Clothing
  - Personal communications ensemble
  - LO organic weapons
- Tactical mobility where terrain permits
  - New power concepts
  - LO "vehicles"
- Lavish use of robotics, especially in MOUT
- Sustainment uniquely tailored to cells
  - Specifics
  - Timing

Experience gained during behind-the-lines patrol actions in Vietnam established several requisites for combat cell survivability. These included stealth, or the ability not to be detected by the enemy; enough organic firepower, smoke and gas for short term self-defense; and to have in place, pre-planned extraction of the force by helicopter or aircraft. These same "rules" apply today.

For the future, we will continue to rely on these and add a central role for dominant situation understanding.

A comprehensive total force approach to using IW can greatly enhance survivability of the combat cells. IW can "encourage" adversary forces to expose themselves to detection, tracking, and effective attack by our remote sensors and weapons. It can also degrade his own C^4ISR resources, making them less effective or misdirected.

Stealth is essential at the unit and individual level. It also applies to insertion, extraction and sustainment capabilities. Our judgment is that there is not enough effort in this area.

The cells require tactical mobility, where terrain permits. We saw the value of mobility in the earlier discussion of operational architectures (the Task Force Griffin analysis and the IDA simulations).

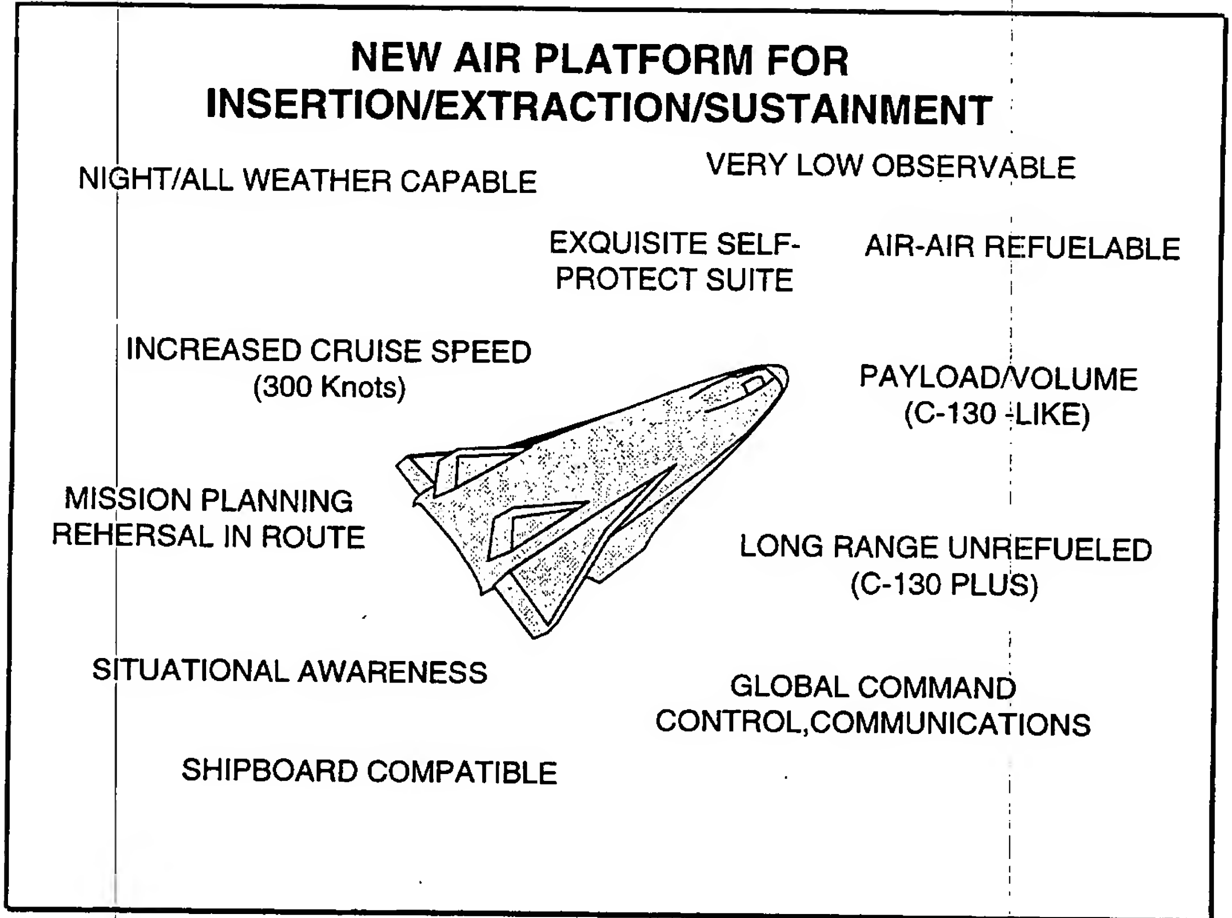
Robotics will be lavishly used, especially in military operations in urban terrain.

INSERTION AND EXTRACTION KEY ATTRIBUTES

- How:
  - Air: with mixed platforms
  - Sea: surface and submarines
  - Conventional
- Planning and Mission Rehearsal
  - Premission
  - Enroute
  - Deployable
- Threat Avoidance and Survivability
  - New Technologies needed especially in Air Platforms
- Global, Secure, Assured Communications
- Common Situation Understanding Across JTF AOR

There is some classified activity in the areas of insertion and extraction capability. We envision troops being put in and taken out by several means, some of which are very unconventional. Planning and mission rehearsal are key for pre-mission, en route, and using deployable systems. We note Special Operations Forces (SOF) have a sophisticated system in development today that accomplishes some of these needs.

Better communications are required than we have today. Using UHF SATCOM for assured global communications is hardly going to be a survivable concept in the 21st century. There must be a common situational understanding across the whole JTF AOR.



Inserting, extracting and sustaining the ground forces in a variety of future contingencies will require a new air platform. Desired features highlighted in the chart include very low observability, carrier compatibility and C-130 like range and payloads. In our judgment, the V-22 will not adequately meet the anticipated requirements of the 21st Century.

SUSTAINMENT IN 2015 FOR THE LEADING EDGE STRIKE FORCE WHAT'S DIFFERENT?

- Significant reduction in tonnage moved to shore
  - Indirect fires from afar
  - No heavy direct fires in a cell
- Sustainment knowledge system anticipates demands and schedules
  - deliveries of the right stuff to the right place at the right time
- Deliveries go directly to combat cells via unique means
  - Particularly important for counter WMD operation: means to neutralize after site is located
- If something breaks, replace with new vice extraction for maintenance

The differences in sustainment that we anticipate for the 2015 Strike Force from our current operations are several. We will have a very significant reduction in tonnage moved to shore because we are bringing in indirect fires from afar, and we are not giving the cells heavy direct fire equipment. We will have a knowledge system that anticipates demands, and schedules deliveries of the right stuff to the right place at the right time. The deliveries will go directly to a combat cell using unique delivery means such as precision guided, powered parafoil vehicles. If something breaks in the first two weeks, we will not bring in a maintenance crew to attempt repairs — we will simply "park" the damaged item and bring in a replacement. Repairs will be deferred.

Much more funded effort is needed to develop reliable from-the-sea/air methods to sustain forces ashore without huge logistics footprints created ashore.

THE FUTURE OF COMBAT SERVICE SUPPORT

CSS Support For A 3,000 Man Brigade For 30 Days

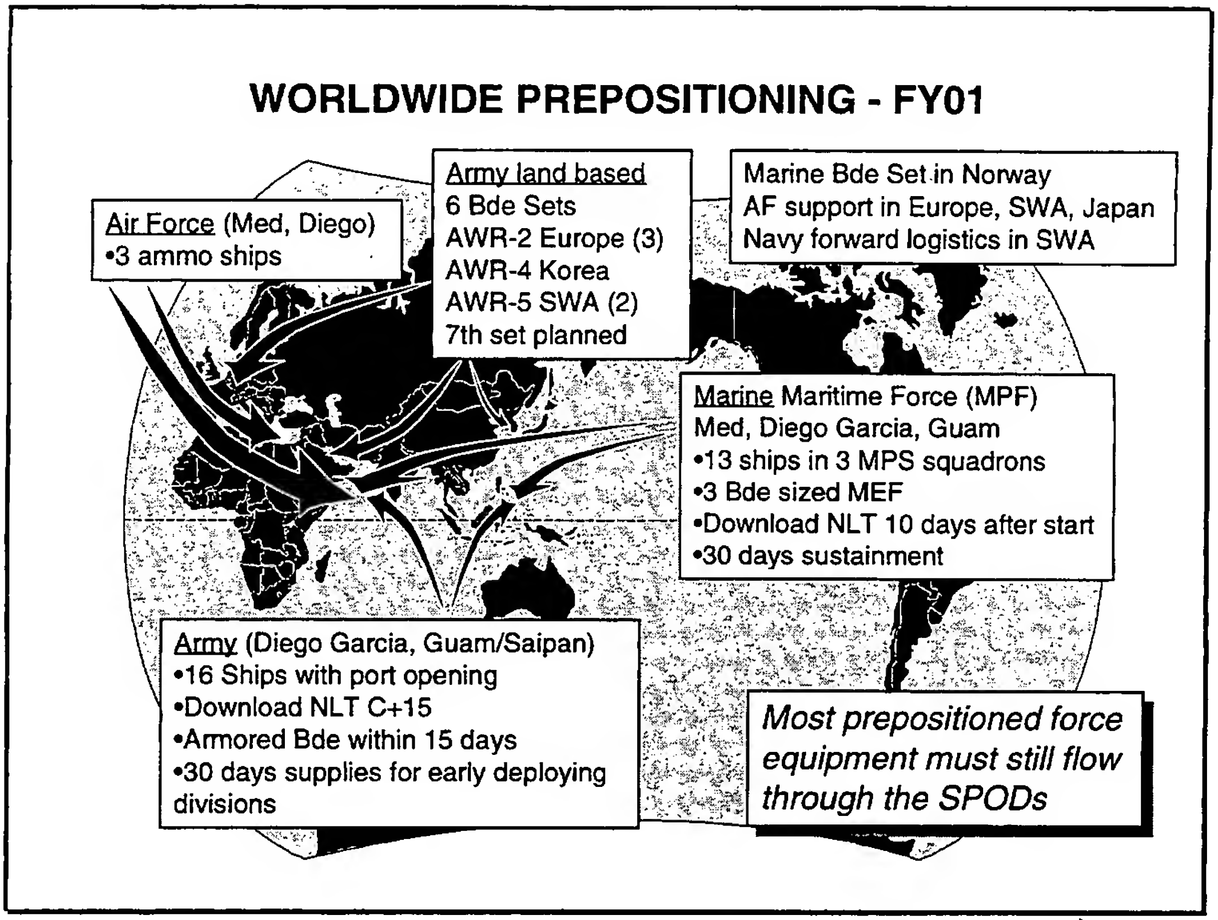
Class of Supply	Current Footprint	Possible Future Footprint
Class I (MRE)	270,000 meals	No Change
Class I (Water)	1,350,000 gals	*Treated Indigenous Water 30% Footprint Reduction*
Class II (Consumables)	3,400 batteries	*300 batteries (rechargeable)*
Operations Ashore	Prototype Windmill Generator	Solar Battery Charger
Class III (Bulk Fuel)	100,000 gals (avg.)	*Alt. Fuels, Freeze-dried* 50% Footprint Reduction*
Class V (Ammo)	350 tons	*Stand-off Precision 70% Footprint Reduction*
Class VI (Repair Parts)	Approx. 30,000	*Tailored Maint/Distribution 75% Footprint Reduction*

*Requires H^2O to re-hydrate; can be indigenous

This is an example of the current combat service support footprint today, if we must support a 3000-man brigade for 30 days. We list the requirements for food, water, batteries, gasoline, ammunition, and repair parts.

Our goal for the future is shown in the last column. While we do not envision the ability to reduce the food supply requirement, we do expect that techniques and technologies such as those listed can reduce the rest of the footprint significantly. One issue is how to bring power ashore. An approach is very portable fuel cells to generate electric power. Innovations like freeze-dried fuel could reduce the fuel footprint by 50 percent. Precision strike from afar enables a very large reduction in ammunition footprint, and tailored maintenance can dramatically reduce the repair support footprint.

Direct delivery to the ultimate user will reduce the need for redistribution, thus reducing vehicles, fuel and personnel; and Combat Service Support, in the combat zone.



This chart, reflecting the importance of prepositioning in U.S. strategy, depicts the stocks prepositioned around the world, both afloat and ashore. Many of these support heavy brigades. However, if these stocks were to be moved today for immediate use, they would have to be brought through a port. Because of potential vulnerabilities of port facilities, there is a serious need for an over the beach, off loading system capable of operating in rough weather (above seastate 3). We note one promising concept, called the Landing Ship Quay/Causeway (LSQ/C) in early design for the Navy.

This is an area needing more attention and a good candidate for an ACTD in which one or two LSQ/C ships could be built and tested in realistic across the beach operations.

LOGISTICS

Precision Resupply

Joint Precision Offset Delivery System (JPODS)

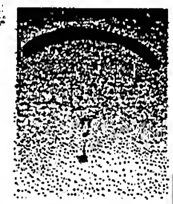
- Clandestine Resupply
- Scaleable Vehicle
- Accurate in Adverse Weather
- Uses Existing Technology
- Propulsion Could Be Added to Increase Range

Parafoil Systems

1,000 lb

- Mass Resupply
- Large Payloads
- GPS Guided

6,000 lb



10,000 lb

Characteristics Summary

JPODS		Parafoil
300 - 2000	Payload Wt - lb	1000 - 40,000
15 - 90	Payload Vol - ft^3	as Req'd
Up to 50	Range - NM	14 From 30K ft
100	Accuracy - m	Wind Dependent
Low	Signature	High
1 - 4	Time of flt - min	10 - 20
Various - A-10, B-2, C-130, C-2, C-17, F-15, F-16, F/A-18	Delivery Systems	Transports - C-130, C-17

We have considered several advanced ideas for moving materiel ashore. One is the Joint Precision Offset Delivery System (JPODS), which uses an affordable missile system that can bring in supplies (weight range 300-2000 lb) over insertion distances up to 50 nautical miles. Another concept is the guided parafoil, which can be powered. Unpowered parafoils today can support up to 40,000 lb, but the range is rather limited (~14 nautical miles) if dropped, for example, from altitudes of 30,000 feet. Longer insertion ranges would be desired. This area is in urgent need of attention and some type of ACTD or ATD.

TRAINING

- Training is near (or at) the top of the list of determinants of victory
- A "contingency military force" must be more highly trained than the cold war force
- Not enough focus on dealing with uncertainty

Training is critical. It is near, or at, the top of the list of determinants of victory. The training edge for U.S. forces is at least as important as the technological edge. Training, including joint training, to a higher standard sets U.S. forces apart from other nations today. Through superior training, less modernized units can outperform better equipped units.

Dealing with uncertainty, always critical in warfare becomes, if anything, even more essential to successful operations of the dispersed combat cells. The tools of enhanced situation understanding will not eliminate uncertainty but rather provide the means to cope better with uncertainty. There is not enough focus in current training programs on dealing with uncertainty. Further, this area is in need of attention for the development of new, combat cell-level virtual reality simulators using innovative means to insert cell fighters into realistic combat conditions/operations.

NEED FOR CONCEPTUAL SHIFT IN TRAINING

- Must develop lifelong learning skills
- Current methods will not evolve sufficiently
- Cannot simply overlay technology on our current systems

- ATTRITION WARFARE
  - Group Training
  - Lines/Schedules
  - Frontal Attack/Rote memorization
  - Focus is on system's ability to instruct
  - Rifle carriers
    - Dependent
    - Inflexible

⇒

- MANEUVER WARFARE
  - Individualized Training
  - Chaos/Disorder
  - Maneuver/Problem Solving
  - Individual responsibility for own development
  - Riflemen
    - Resourceful
    - Adaptable
    - **Thinkers/Learners**
  - **Focus on Uncertainty and Dealing with Same**

We envision a concept shift in training, from today's attrition warfare mentality (where the training focus is directed on the areas listed) to a maneuver warfare mentality (see attributes listed in the chart). This leads to greater focus on the individual, on chaos and disorder, and on the rifleman as a thinker/learner (i.e., turning riflemen into pilot-equivalents). The overarching difference is an emphasis on uncertainty in warfare and how to deal with it.

Changing the Culture

MAJOR CULTURAL CHANGES MAY BE REQUIRED IN ORDER TO ACCEPT ELEMENTS OF THE NEW CONCEPT

- Troops without artillery
- Everybody can know what everyone else knows
- Small cells "controlling" expensive systems
- Many sensors (National, Theater, Local) managed as a single entity
- Unmanned armed platforms doing the job of manned platforms
- Robots on the battlefield
- And many, more

THIS MAY BE THE TOUGHEST PROBLEM OF ALL

Challenges to the "current culture" include: the JTF commander controlling and tasking national sensor systems as well as all theater assets; combat cells empowered to control sensor systems and indirect fires at least for a period of time as required; and, armed UAVs doing the jobs heretofore done by manned tactical aircraft or bombers.

These and other new approaches must be addressed in the context of culture shifts — a subject deserving far more study than we could devote.

Section VI
Recommendations

"It is worth noting that nothing is harder to take in hand, more perilous to conduct, or more uncertain in its success, than to take the lead in the introduction of a new order of things"

Nicolo Machiavelli

RECOMMENDATIONS

- Establish "Try Before Buy" environment to explore and exploit these distributed/expeditionary force concepts
  - Create, model, experiment, Red Team, learn...
  - Augment the emerging service initiatives: Sea Dragon, Army After Next
  - Support by redirected analysis and simulation activities
- Select executors now to make all this happen & evolve the concepts
- Support critical systems and technology enablers
  - Accelerate the development of the information dominance architectures
  - Accelerate the incorporation of available technology into the light forces (+ $50M/yr split between Army & Marines)
  - Implement ATDs & ACTDs (existing & new)
- Prepare to establish a joint operational task force by 1998 to be the focal point for transitioning the concepts

We offer three sets of recommendations. All would require action by the most senior Pentagon leadership: the Secretary of Defense and the Chairman of the Joint Chiefs of Staff.

The most important recommendation is to establish a mechanism and process to explore and exploit new joint expeditionary force concepts that offer potential revolutionary enhancements in the effectiveness of rapidly deployable forces (not necessarily limited to the ones described in this report). This would encompass the emerging relevant Service efforts; address doctrine, CONOPS, tactics and training; and would involve extensive experimentation (of all sorts). We further recommend that a new joint effort be created to lead this effort. This effort would be organized, not around particular technologies or systems, but rather a military mission.

Modeling, simulation and analysis will be critical for this effort. However we have serious concerns that the DoD analysis and modeling culture will not be able to provide the type of support needed to explore and exploit these new warfighting concepts. The current culture is characterized by bureaucratic review, accredited analysis, mechanical and data poor models, few accredited scenarios and point threat estimates. It also does not capture the value of command, training and situational understanding. It suppresses uncertainty and

risk. A whole new approach is needed to change this environment. We offer some suggestions in Section V, Volume 2, but this problem was beyond the scope of our study.

Our second set of recommendations relates to ensuring the development of critical enabling systems and technologies. There are recently initiated activities, including ACTDs, that are relevant, indeed important, to the expeditionary force concept. We identify several of these and recommend that they continue to be supported. Other ATD and ATCD like programs will also be needed to support the concept and we offer a list of candidate topics.

These distributed force concepts will go nowhere without a robust information infrastructure. Such an infrastructure cannot be built in our lifetime without embracing commercial technologies, practices and standards. We offer several recommendations to help accelerate the process. These include designating the USD(A&T) and ASD/C^3I as the enforcers of compliance to the "building codes" specified in the Joint Technical Architecture.

We also recommend allocating funds (~$50 million a year for a few years, split between the Army and Marines) to buy some modern communication, navigation, and targeting equipment for the active light infantry forces. $100, 000 or less can go along way towards bringing at least 1980's technology into the light infantry squad, a big step from the obsolete equipment and materiel they have now. There are about 2,500 such squads in the active forces (Army and Marine Corp), so $50 million a year for a few years can upgrade almost all the active light infantry force. These enhancements will not only improve their ability to accomplish today's missions but also allow them to "play" in the development of the distributed force/ combat cell concepts.

Our last recommendation is to establish a Joint Expeditionary Task Force (under USACOM), to be operational in 1998, to be the lead warfighter customer for the tactics and technologies that will evolve from the above efforts.

Several of these recommendations are elaborated upon in the remainder of this section.

MAKING IT HAPPEN

- Pick executor(s) with the:
  - Commitment & enthusiasm to explore & exploit new joint expeditionary forces
  - Capabilities to demonstrate robustness of concepts
  - Experience in turning demonstrations into real capabilities
- Executor options include:
  - A CINC -- USACOM -- as a primary architect
  - The Services working together
  - One service -- as executive agent -- working with the other Services

Identifying criteria is easy. Identifying the ideal candidates is not. It is still difficult to find a home in DoD for an activity that is so intrinsically joint and so new and novel.

A CINC would bring the requisite joint perspective, but their current priorities, responsibilities, resources and staffing would present considerable start-up problems for the execution of the experimental program we envision. The Services bring the resources and experience needed to explore and transition new concepts, but jointness and efficiencies would suffer particularly if cooperation were "optional."

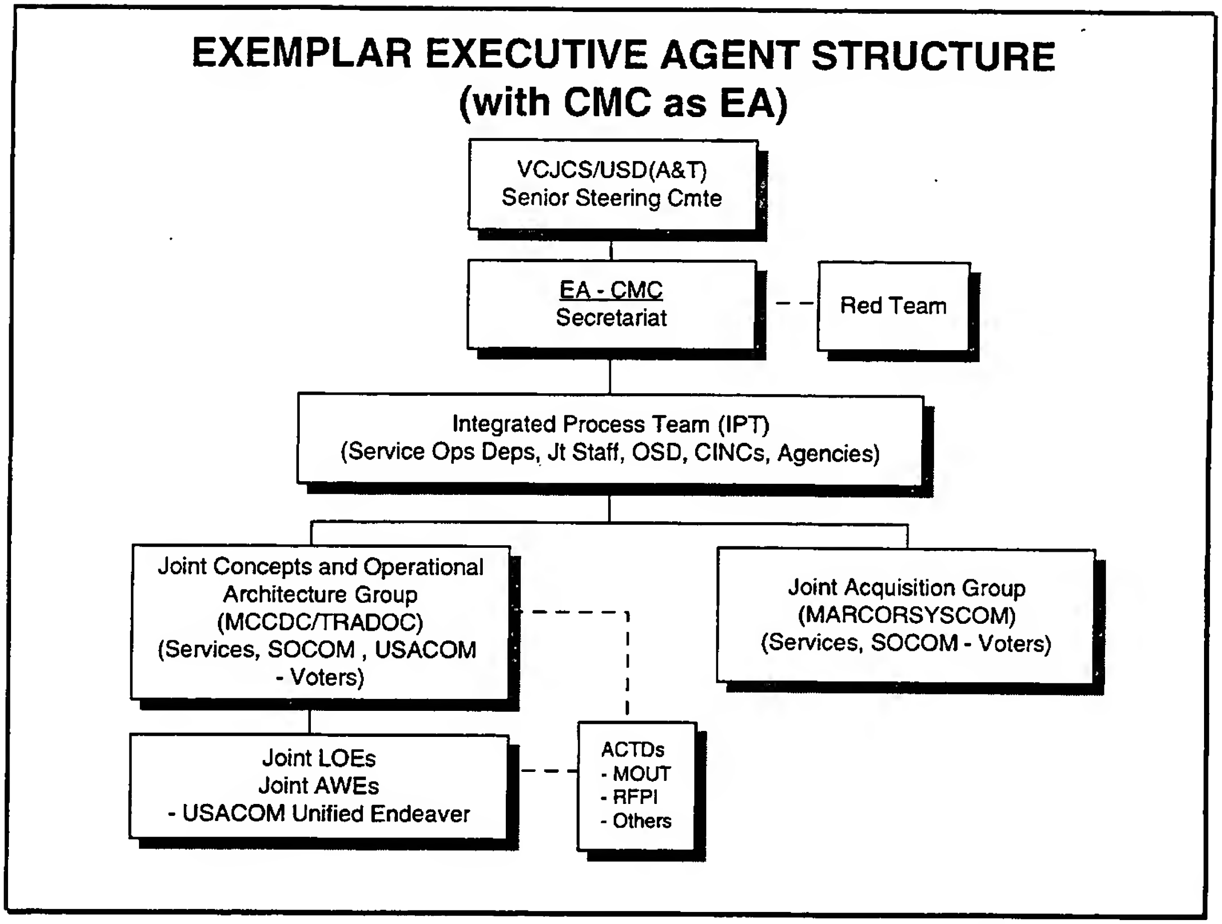
Therefore, in order to secure the commitment and resources needed to pursue this new joint concept, we recommend that a Service be designated as executive agent for a joint effort. (Another alternative would be to establish a new joint organization perhaps reporting directly to the Joint Staff.)

ESTABLISH A JOINT EFFORT TO EXPLORE AND EVOLVE THE CONCEPT

- Establish a dedicated, **joint effort** to develop, test, analyze, and evolve new expeditionary force concepts
  - Explore and test concepts through a series of LOEs/AWEs
  - Begin exercising promising concepts in 1997 USACOM Unified Endeavor Exercises
  - Focus on providing remoted support (C4ISR, Fires, Logistics) to both distributed and aggregated ground teams
- Appoint a Service Executive Agent to lead this effort
- Provide money for Executive Agent (EA) to reinforce/accelerate ongoing service/SOCOM initiatives and to enable immediate procurements of COTS operational capabilities supporting these concepts
- Require EA to provide metrics and yearly "deliverables" to make this real for today's decision makers and operators
- Develop analysis tools that can capture lesson learned in a constant framework and can support future budgetary decisions needed to implement the evolving concept

Who: SecDef & CJCS
Cost: Growing to >$200M/yr

Our cost estimates are not very precise. We do know that it cannot be done for tens of millions per year, nor will it cost billions. At least $100 million per year will be needed just to conduct the high quality LOEs/ AWEs essential to learn how to exploit the strengths and mitigate the weaknesses of the concept.



This example of a possible Executive Agent (EA) structure is similar to the one established for non-lethal weapons with the Commandant of the U.S. Marine Corps as the EA.

ACCELERATE THE FIELDING OF THE INFORMATION INFRASTRUCTURE

- Develop joint war fighter, (operational) architecture that addresses:
  - Operations concepts
  - Processes and procedures for information generation, condition, fusing & use
  - Weapon, sensor, platform functional characteristics
  - Assignment of functions
  - Force structure

Who: JCS lead (w ith the EA for the expeditionary fire concept)
Cost: $10Ms

- Mandate joint technical information architecture that:
  - Addresses coherent data formats, protocols, message standards, interfaces, etc.
  - Enables "open systems"
  - "Building code" for information architecture

Who: USD(A&T) and ASD/C³I
Cost: $2/3M

- Implement Joint Information Infrastructure Systems Architecture:
  - Migrate legacy systems
  - Integrate commercial systems

Who: Services/C⁴I
Cost: >$1.5B over 5 years

The Task Force recommends specific actions to accelerate the fielding of the information infrastructure. We follow the recent and useful practice of dividing the information infrastructure into three inter-related architectures: operational, technical and systems. An absolute necessary, (albeit not sufficient step), is to enforce compliance to a joint technical information architecture. The Army has made progress in this direction by using the Acquisition Executive's power to control funds. We recommend a similar DoD-wide arrangement be established with the USD(A&T) and ASD/C³I as the enforcers of compliance in the joint area. They would need a small group to advise them of the compliance issues as they arise and require resolution.

SUPPORT EXISTING/CANDIDATE ACTDs AND ATDS IMPORTANT TO THE CONCEPT

- Fire and lethality
  - Rapid Force Projection Initiative (RFPI), counter MRL Fire and lethality
- Information infrastructure
  - Battlefield Awareness and Data Dissemination, Secure Personal Communication
- Sensor systems and situational understanding
  - Combat ID, Rapid Battlefield Visualization, Semi-automated Image Processing, Integrated Sensor Tasking, Precision Target Identification, Counter CC&D, Unattended Ground Sensors, HAE, MAE, TUAV
- Insertion, extraction, sustainment and survival
  - Joint Logistics ACTD, Survivable Combat Vehicle
- Exercises, training, and operations
  - Digitized battlefield, MOUT, Sea dragon
- Non-Lethal Systems

We are not making a blanket endorsement of all of these efforts, only urging that on-going efforts that can support the expeditionary force concept be accounted for and supported.

The programs listed above vary considerably in their maturity. Some have products already in the field (MAE), while others (e.g., Sea Dragon) exist only on paper. Still others (e.g., MOUT) appear to need a stronger central role for concepts of operations to provide a comprehensive and coherent framework to evaluate technologies. A major issue is the need for effective non-lethal systems for crowd control and suppressing others without casualties.

INITIATE ACTDs AND ATDS: POTENTIAL CANDIDATES INCLUDE

- Fire and lethality
  - Loiter weapons, armed UAVs, sea-based fire support (e.g. long range guns), dynamic force and fire management, dial-a-lethal warheads , new concepts for using long range aircraft (e.g. arsenal aircraft)
- Information Infrastructure
  - Tactical/ personal information ensemble, communication payloads for UAVS, urban comm nets
- Sensor systems and situational understanding
  - Sensor galaxy (from satellites to smart UGS) management, "CEC" for ground war, improved multimode sensors for FOPEN & urban environments, Enhanced JSTARS
- Insertion/extraction, sustainment & survival
  - Stealth transport aircraft, Team mobility vehicle, GPS parafoil delivery, non-lethal weapons, stealth clothing/treatments, BW monitoring at a distance, anti-sniper systems
- Exercises, training and operations
  - Synthetic theater(s) of war at combat cell level, IW, Distributed force/combat cell simulations, stay-at-home and network training devices

Finally, we recommend the initiation of new ACTDs and ATDs. More detail on these and other technology concepts is provided in Volumes 2 and 3.

Section VII
Conclusions

FOUR CRUCIAL ENABLERS

- Fielding the information infrastructure
  - Robust communication
- Turning situation awareness into situation understanding
  - Managing sensors, information in a conceptual context
- Making remote fires work
  - Managing ensemble of weapons; important role "loiterers," inflight update
- Operating in dispersed posture
  - Stealth, mobility, insertion, sustainment

The Task Force believes that substantial, possibly revolutionary, enhancements of the effectiveness of rapidly deployable military forces are feasible. We believe that the concepts we explored in this study can be refined, tested, modified, shaped and evolved into fielded capabilities over the next 10-20 years. The Task Force believes that the technology can be brought to necessary maturity to support this time scale within reasonable resource expenditures.

The four enablers shown above complement each other. A robust information infrastructure, connecting all the elements of this distributed and mutually supportive force, provides the basic foundation for the concept. Augmenting any force with remote fires will enhance the force's effectiveness. If remote fires are sufficiently effective and responsive, they can substitute for the force's organic capability, and by reducing weapons and ammo loads, can lead to lighter and more rapidly deployable forces.

The remote fires will be provided by an ensemble of precision weapons delivered by manned and unmanned aircraft, rockets, missiles, and guns. Sea basing and long rang aircraft will be especially important to deal with the situation when in-theater on-the-ground resources are unavailable or limited severely.

Greatly enhanced situation understanding is needed to effectively use this ensemble of remote fires. This will require dynamically managing sensors and information in a CEC-like rich internetted ensemble of geometrically and phenomenologically diverse sensors. To the extent that this capability can turn fleeting observations into tracked targets, it will allow much more efficient use of remote fires by offering more opportunities to strike when the targets are most vulnerable and minimize undesirable effects.

Enhanced situation understanding is also critical to the combat cell's ability to survive (avoid firefights, minimize fratricide), which in turn allows the cells to function in their role as a contributor as well as a user of the situation understanding network.

To the extent that the remote fires help protect the combat cell from fire fights, they also reduce the need for direct fire weapons. This allows the combat cells to be lighter, more agile and more useful in an C^4ISR role which in turn contributes to the effectiveness of remote fires.

The enhanced situation understanding and robust wide band information infrastructure simultaneously enables more centralization and greater decentralized empowerment. Success on the future dispersed battlefield will to a great extent depend on learning how best to dynamically manage additional degrees of freedom.

MR. SECRETARY and CHAIRMAN:

Invest in this vision and you will leave to your successors:

At the least: a potent multiplier for "standard" force concepts and tactics

- Through sensor and information management, and more effective remote fire

A good chance: an even more dramatic increase in the effectiveness of rapidly deployable light forces

- If the concept of distributed combat cells prove robust across a broad range of missions and enviornments

Some possibility: the foundation to a true revolution in military affairs and new dominant modes of warfare

- Perhaps the next major step in the historical trend of increasing dispersal on the battlefield

Appendix A
Terms of Reference

THE UNDER SECRETARY OF DEFENSE
3010 DEFENSE PENTAGON
WASHINGTON, D.C. 20301-3010

ACQUISITION AND TECHNOLOGY

MAR 15 1996

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Terms of Reference--Defense Science Board Summer Study Task Force on Tactics and Technology for 21st Century Military Superiority

You are requested to form a Defense Science Board (DSB) Task Force to address Tactics and Technology for 21st Century Military Superiority. The Task Force should focus on the concept of making relatively small (the size TBD) and rapidly deployable forces (or teams)--specially equipped, trained and supported by remote sensors and weapons--able to accomplish missions heretofore only possible with much larger and massed forces.

The Task Force should address the following questions:

1. What would be the realistic mission expectations for these small forces and how does this concept fit within larger military strategies and force employment?

2. What operational and technical capabilities are necessary to greatly enhance team effectiveness, flexibility and survivability?

3. How and by what time frame can the DoD realistically expect to turn such a concept into an operational capability?

In developing its findings and recommendations the Task Force should:

- Develop an operational approach to the small team concept which considers command and coordination, targeting and fires, maneuver and mobility, survivability and sustainment.
- Identify realistic missions to include offensive, defensive and "presence" as a form of deterrence of adversaries and reassurances of friends. Missions in built-up urban areas should be included.
- Assess vulnerabilities and potential adversary countermeasures.
- Examine innovative tactics such as the employment of national sensor systems, UAV-based sensor and communication systems, and long range precision fires directed by the small teams.
- Identify the necessary technical and operational capabilities for team insertion and extraction, C3 and coordination, sensors to detect and localize targets and provide situation awareness to deployed teams, preferred remote weapons and platforms, team survivability and the employment of stealth.

- Examine technical concepts and technologies which may impact these tactics and operations/logistics in littoral areas (eg: arsenal ship, unmanned tactical/strike aircraft, robotics, and shallow water ASW.
- Develop an evolutionary roadmap and schedule to realize the concepts to include investment priorities for technology, CONOPS, tactics and doctrine, organization, implications for training, equipment and logistics, the fit with coalition warfare, estimates of cost, and finally, identification of potential obstacles to success.

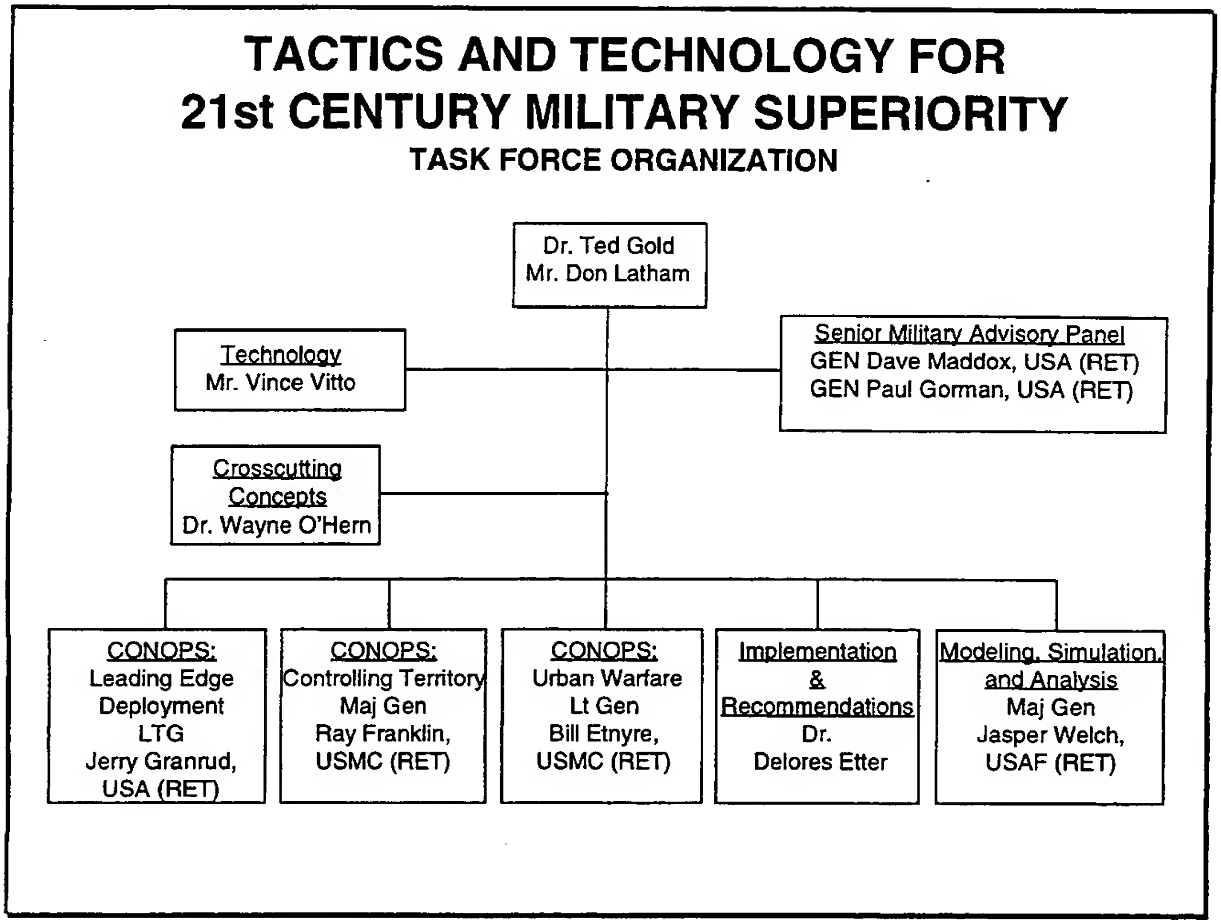
The study will be jointly sponsored by the Chairman of the Joint Chiefs of Staff and the Under Secretary of Defense (Acquisition and Technology). Dr. Ted Gold and Dr. Don Latham will serve as Co-Chairmen of the Task Force. COL John Fricas, USA, of the Office of the Deputy Under Secretary of Defense (Advanced Technology) and Col Ray Cole, USMC, Chief, Land and Littoral Warfare, Joint Warfighting Capabilities Assessment will serve as co-Executive Secretaries. LTC T. Van Horn, USA, will be the DSB Secretariat Representative.

The Task Force will be operated in accordance with the provisions of P.L. 92-463, the "Federal Advisory Committee Act," and DoD Directive 5105.4, the "DoD Federal Advisory Committee Management Program." It is not anticipated that this Task Force will need to go into any "particular matters" within the meaning of Section 208 of Title 18, U.S. Code, nor will it cause any member to be placed in the position of acting as a procurement official.

Paul G. Kaminski

Paul G. Kaminski

Appendix B
Study Participants and Organization



This DSB Task Force differed from most previous DSB studies in its size and composition. This unusually large number of participants (this was one of the largest DSB Task Forces ever) reflected our desire to involve many minds and organizations in addressing how novel tactics and emerging technologies can enable new military capabilities. Similarly, the unusually large percentage of military personnel (retired and active) stemmed from the centrality of military concepts and operations in our tasking.

The enthusiasm, effort, and commitment of the participants, Task Force Members and government advisors were exceptional. The above chart shows the study organization for the summer session. The group proved to be quite adaptable to reorganization several times during the months leading up to the summer session (much of the work must be done in this preparatory phase) as we sought to bring different perspectives to bear on the problem.

Five of the panels have produced reports. These reports, of the three CONOPS panels, the technology panel, and the Modeling Simulation and Analysis panel, are contained in Volume 2. Volume 2 also contains work done for the Task Force by others: the Army's TRADOC Analysis Center, RAND, the Institute for Defense Analyses, the CIA, and USSOCOM. Inputs from the last two are found in the classified Part 2 of Volume 2.

DSB Summer Study
Tactics and Technology
for 21st Century Military Superiority

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Appendix C
Enabling Technologies

1996 KEY ENABLERS
SYSTEMS AND TECHNOLOGIES

- Fires and Lethality
- Battlemanagement, Command and Control
- Information Infrastructure
- Sensor Systems and Situational Understanding
- Insertion, Sustainment and Extraction
- Force Survival
- Exercises and Training
- Urban Operations
- Nonlethal Weapons

TECHNOLOGY AREAS RECOMMENDED FOR FOCUS AND INVESTMENT BY LAST YEAR'S DSB SUMMER STUDY

- Intelligence/surveillance/reconnaissance
- Defensive information warfare
- Countering WMD – especially BW
- RISTA and precision strike
- Ballistic and cruise missile defense
- Strategic mobility
- Littoral ASW and counter mines
- Deep underground facilities
- MOUT and operations other than war

The 1995 DSB Summer Study on Technology for 21st Century Military Superiority recommended the above areas for increased attention and investment. Most of these areas remain relevant to the narrower – expeditionary force – focus of our current study. Some of these relevant areas – littoral ASW, countermine, cruise and ballistic missile defense, deep underground facilities, BW defense, strategic mobility – are not addressed in detail in our study either because they are beginning to receive adequate attention within DoD or are being addressed by other DSB efforts.

This appendix elaborates on the critical technology enablers for the expeditionary force concept. It follows the organization of Chapter V and covers: fires and lethality; battle management and command and control; information infrastructure; sensors and situation understanding; insertion, sustainment, and extraction; ground forces survivability and exercises and training. Because of the unique challenges they present, military operations in urban terrain (one of the recommended areas from last year's DSB study), and non-lethal weapons are treated as a separate topics.

More detail on all these topics is provided in Volume 2 (particularly Section VII) and Volume 3.

FIRES AND LETHALITY

Critical Needs: Assured, easy-to-call, multi-mode <<$$/ round, based outside combat area

Systems:

- Guardian loitering armed fire UAV
  - Hundreds of munitions
- Sustaining hi-volume, hi-rate Capable platforms
- Munition Types
  - Loiter, cruise, hypervelocity delivery
  - Multi-effects warheads

Comments:

- Emergency support, hi-user confidence, effective fires
- Galaxy of systems provides almost all Indirect Fires
  - need to manage the galaxy
- Mixes of delivery, seekers, effects
  - Inflight updates
  - Light Wt/Vol
  - Report back for BDA

Technological Enablers:

- Low $$ precision guidance
- Light-wt. multi-effect WH
- Low $ light-wt. propulsion
- Foliage & building penetration seekers

There is a need for a new family of indirect fire weapon systems which can deliver precision fires against any tactical targets (fixed or mobile) from the air or surface-to-surface launched, from stand off ranges of perhaps hundreds of miles, to air delivered munitions from manned or unmanned aircraft at shorter ranges. Some of those new weapons should be capable of in-flight update after launch, to deal with newly developed target location data, as the long range missiles are approaching their targets. A further need is to also enable some weapons to loiter over the target area to deal with rapidly evolved critical targets or to deliver emergency fires to support combat cells under direct attack.

These new, indirect fire weapon systems must be much less costly than today's weapons such as Tomahawk, ATACMS, and CALCM.

The management, deconfliction, and cost effective allocation of these indirect fire weapon systems will be intimately dependent on the quality and timeliness of supporting sensor data, such as precise target locations, classification and vulnerabilities, plus assured real-time knowledge of all friendly forces locations, status and movements. In other words, exquisite situation understanding is required to create effective remote fires.

For military operations in urban terrain (MOUT), unique, new weapons and sensor systems are also required.

BATTLEMANAGEMENT, COMMAND AND CONTROL

Critical Needs: Sophisticated decision aids; commander's associate; greatly improved humans interface to the information infrastructure; semi-automated battlespace deconfliction in near real-time

Systems:

- JFACC After Next
- Battlefield Awareness Data Distribution (BADD)
- Common Operating Environment (COE)
- Command-Level Simulations
- Distributed and dynamic force management
- Automated course of action assessment tool

Technological Enablers:

- Rugged, low power, low weight, high performance displays (many sizes)
- Significant advances in decision aiding technologies
- Resource deconfliction and scheduling aids

The Commanders' (from theater to combat cell) ability to observe, orient, decide, and act can be greatly enhanced if the future BM/C^2 systems can:

- provide theater-wide sensor data, fused together for a cleaner understanding of the operational situation,
- provide this information to decision support tools,
- provide modeling and simulation capability for execution analysis to "fly the missions ahead of time,"
- provide robust communications with over-the-horizon connectivity to extend operations and the Commander's control both into and out of the theater, and into and out of the cockpit, and within and between combat cells,
- be employed with less people, time, support tail, and airlift, facilitating rapid deployment and operations.

There are many systems currently under development that will go a long way to improving the BM/C^2 capability to support future military operations. The JFACC after next ACTD is a DARPA program designed to provide an adaptive, mission tailored system to support decision making for short-dwell targets and responsive battle damage assessment. The Battlefield Awareness Data Distribution (BADD) ACTD is another DARPA program

designed to address the issues of database mining and intelligent satellite communications broadcast dissemination based on warfighters requirements.

Additional effort will be needed on systems to allow command level simulation capability, distributed and dynamic force management capabilities and automated course of action assessment tools. These systems will require rugged, low power, high performance displays and intelligent software agents for decision, deconfliction and scheduling of resources under a Commander's control.

INFORMATION INFRASTRUCTURE

Critical Need: Tailored information, when and where required: precision POS/NAV, common reference grid, situation displays, multi-mode services

Systems:

- Tactical information infrastructure (TII) : Integrated fiber/SATCOM/wireless systems
- Network of UAV's for robust connectivity
- Warfighter's personal information ensemble
- Networked software agents to provide information fusion, & dissemination functions

Comments:

- Network security is critical
- Opportunity based on HAE/UAV's and software Comm developments
- Based on a commercial cellular and digital assistant technologies
- Fundamental R&D programs must be initiated

Technology enablers:

- Heterogeneous network integration and protocols
- Intelligent software agents
- Network security
- LPI/AJ techniques for local communications

To the maximum extent feasible, the infrastructure takes advantage of commercial technology and networks, by utilizing open-systems standards and protocols, and minimizes the use of Service or function-unique hardware and software. For applications where military-unique functions, such as anti-jam, low probability of intercept, spectrum utilization, etc., are required, military products will be developed or adapted to interface with the overall architecture.

SENSORS AND SITUATION UNDERSTANDING

Critical Needs: Shared, comprehensive, composite fire control quality understanding of the battleground - "CEC for ground picture"

Systems:	Comments:
• Multimode, All Weather Radar and EO/IR Sensors	• Tier 2+, Tier 3-, JSTARS, U2 ..Limited Performance
• FOPEN MTI/SAR Sensors	• No systems under development
• Long-range Chem/Bio Warning and In-situ ID	• Need lasers and microchip detectors
• Multi-source Integrated Data Bases for Exquisite Situation Knowledge	• Many small program lacking coherence
• Autonomous Resource Allocation System for Sensor Galaxy Management	• No single office responsible for sensor coordination
• Very smart, endurance UGS	• Limited capability today
• UAV sensor platforms (including micro air vehicles and helicraft)	

Technological Enablers:

- Multimode Phased Array Radars
- Hyperspectral EO/IR Sensors
- FOPEN Target ID Techniques
- Multi-signature Fusion
- Chem/Bio Microchip Detectors
- Agile Track Modes

Successful operations with distributed combat cells will hinge largely on their ability to understand their environment with much greater detail and accuracy and over larger areas of concern than the enemy. The three critical elements to achieve this dominance are the sensor systems, the sensor management system, and the information management system.

Current efforts to introduce new technologies into sensors and sensors into deployable systems must be expanded to address the ubiquitous situational understanding environment. The recent focus has been on developing space based and airborne platforms for new sensor systems. Attention should be given to the development of advanced phased arrays for SAR and MTI radars with agile mode selectivity and tracking capability. In addition, advanced hyperspectral electro-optical sensors must be developed. Special attention must also be paid to the development of new technologies for detection, tracking and identification of targets in low observable environments (e.g., foliage penetration or seeing through walls), chemical and biological weapon detection, and detection and tracking of people. In addition, the cost and complexity of sensor platforms must be reduced by merging related sensor types into multifunctional systems for a given platform.

Simultaneously, existing and emerging systems must be pushed toward miniaturization to reduce the size, expense, and logistical support of sensors and sensor platforms (especially

UAVs, autonomous VTOLs, and UGS) and associated processing, and control elements. UGS technology, in particular, needs a much stronger push to develop both the sensors (microchip detectors) and the networks needed to bring the sensors together into capable sensor systems. All sensor systems must be tested in realistic environments and developed to allow adaptation to the larger sensor and information management architectures.

The sensor management system must provide the dynamic allocation of disparate sensor resources to meet the needs of a spectrum of users. The development and testing of allocation algorithms are required which accommodate sensor and platform performance and constraints. The principal barrier in this case may be organizational since the sensor and processing assets are owned by the Services or special agencies, and this function demands integration of all assets. Joint testing elevates system wide priorities above the interests of the "owning" organization is critical for moving forward.

The overriding goal for the information management system is "anyone can get what they need and get it at the right time." This area represents the most significant technical and organizational challenge. Considerably more research is needed in target identification and multi-dimensional data fusion. At the next level, the architecture for a responsive, distributed, robust system does not exist. And finally, any work focused on the situational understanding problem must be developed in parallel and integrated with the overall information infrastructure.

INSERTION, SUSTAINMENT AND EXTRACTION

Critical Needs: More survivable air vehicle for long-range insertion and extraction; non-port roll on/roll off discharge capability; assured resupply delivery to remote cells

Systems

Under Development:

- V-22
- Amphibious Cargo Beaching Lighterage (ACBL)

New Concepts:

- Low Observable air platforms
- Joint Precision Offset Delivery Systems (JPODS)
- GPS Guided Powered Parafoil
- Submarine delivered personnel and support

Technological Enablers:

- VLO technologies
- Totally different power generations capability ashore

By the 21st Century, even so-called third world nations and certainly nations such as Iran, North Korea, and Syria will possess potent air defenses and especially shoulder-fired weapons much more capable than today's SA-18. This means that the insertion, sustainment, and safe extraction of forces ashore by air will demand assured air superiority and suppression of air defenses at least during insertion, sustainment, and extraction operations.

The development of a VLO air vehicle (as described earlier in this report) would significantly enhance the capabilities and survivability of the U.S. to insert forces and sustain them under less than perfect air superiority and SEAD operations — at least for a while.

As an alternative to fossil fuel electric power generators, self-contained fuel cells similar to those being considered for powering UUVs have potential to be made very stealthy, generate large amounts of continuous power for approximately two weeks and more before refueling (or thrown away), and thus provide a reliable power source for the recharging of batteries of all types. If reliable electric power sources were available in the theater, then electric-powered utility vehicles to support the combat cells could be feasible.

New concepts for sustainment include precision air delivery using powered parafoil-like devices and the Landing Ship Quay/Causeway (LSQ/C) being designed for the Navy.

FORCE SURVIVAL

Critical Needs: Improved Survivability of Small Units and Individuals

Systems:

- Individual
  - Weapons
    - High Power Microwave "Rifle"
    - Silent (no signature) weapons
    - "Tagging" Weapons
    - Non-lethal/lethal; Over/Under shotgun
  - Personal information ensemble
  - Stealth combat clothing
  - "Stimulants" for endurance
  - Physical monitoring & alarm system
- Combat Cell
  - Enduring situation understanding
  - Long endurance propulsion mobility vehicles with VLO
  - Reliable, accurate, urgent, remote fires

Comments:

Technological Enablers:

- Robotics, lightweight, lethal individual weapons, long endurance power sources, VLO technologies

For military operations in urban terrain (MOUT), combat cell survival can be significantly enhanced through the employment of robotic technology. Tele-operated robots supporting combat cells in 2015 would be sufficiently human-like in appearance/behavior to be the first to draw enemy fire when exposed, carry sensors and weapons for countering snipers, and be the first through the door in securing buildings.

New, stealthy individual weapons, weapons which can be used to tag targets, stealth clothing and very capable unattended ground sensors are all part of the combat cell survivability ensemble. Unfortunately, today these technology areas are funded at very low levels and no robust program exists to see them into fielded capability. Again, the key enabler to combat cell/individual survivability will be the ability to provide assured, exquisite situation understanding.

For some terrain, combat cell survivability will be strongly influenced by the ability of the cells to move (covertly if possible) using some form of powered vehicle.

EXERCISES & TRAINING

Critical Needs: Significant changes to exercises & training procedures and technologies will be necessary

Systems:	**Comments:**
• Train using the TII • Train before, enroute, & during operations on one system • Global access for distant learning • Total joint force training readiness diagnostics • On-call access to virtual situational training • Tailored exercises at home stations • Provide linkage between fielding of technologically advanced equipment & the training necessary to optimize its employment • Increase use of unit mission rehearsal systems and individual simulators	

Technology Enablers: Prototype joint combat and exercise training centers to learn not to prove; virtual systems; training diagnostics

The training of the combat cells, their leadership, and the supporting air and naval forces as a tightly integrated joint force is of equal importance to the technological capabilities of the force. Training methods will have to improve as rapidly as the weapons, sensors, and other capabilities that the force brings to bear in combat.

Innovative, virtual reality simulators for the individual and combat cell, which puts the soldier/marine into the terrain "dirt," weather, and other realities of combat must be developed.

URBAN OPERATIONS

Critical Needs: Extend situation awareness beyond enemy lethal zone, robotics assistants, improved non-LOS, lethal & and non-lethal weapons, remote weapon basing, personal protection, personal information infrastructure

Systems:

- Reconnaissance micro UAV
- Robotics
  - Scout
  - Breacher
  - Barrier
  - Mule
- 3D personal location/information infrastructure
- Breaching weapon, tunnel & occupant detector
- Assured communications in tunnels/buildings
- EO, thru-wall, chem/bio detectors
- Human, mine, booby-trap detect & ID sensors; lethal/non-lethal weapons
- Counter sniper system

Technology Enablers:

- Thru-wall human & explosive sensors
- Micro EO sensors
- Non-LOS weapons
- Less-than-lethal munitions & barriers
- Language assistance processors
- Squad-level firefinders
- 3D personal location system

Technology can enable more effective urban operations in the future. The virtual line of sight could be aided by such advances as through-the-wall radars, non-line-of-sight weapons, and small robotic and airborne assists for seeing and communicating around corners or obstructions. In sorting noncombatants from combatants, locally controlled airborne and ground assets with high resolution sensors to detect, for example, sniper fire and to provide accurate layouts and position, especially inside buildings, would allow much more effective pinpointing of the enemy. To address mission objectives for minimizing collateral damage and neutralizing adversaries in the midst of non-combatants, non-lethal weapons will be critical parts of the unit's tool kit.

UAVs with wingspans of a few centimeters could revolutionize airborne surveillance for the local unit over short ranges, in both close terrain and urban environments. The technical challenges for developing such a platform include small, long life power sources and stable aerodynamics at the low Reynolds numbers characteristic of such a small vehicle.

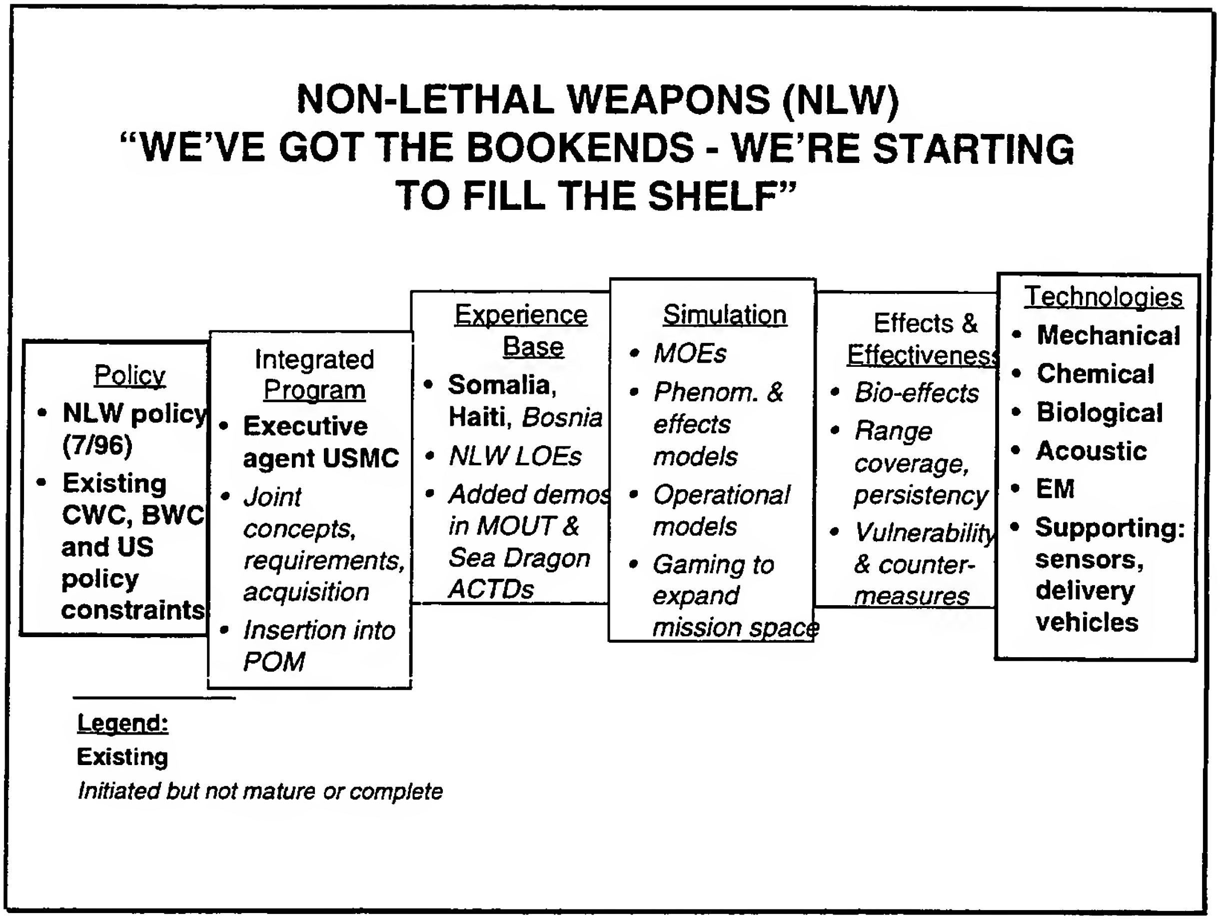
Complementing the micro airborne platform are small ground robotic platforms, disguised as commonplace articles (litter, construction materials, etc.). These platforms (and possibly some larger) allow covert entry into buildings for mapping, specialized detection, communication links, sentry duty, seeing around corners — in short, all those functions

that represent significant risk to the individual warfighter as he enters an unknown, constrained environment or needs someone/thing to cover his backside.

Micro platforms without miniature sensors are of little interest. However, technology offers the promise of such sensors, which include WMD sensing (chemical, biological, nuclear) and multi-spectral IR imagers.

There are many roles for non-lethal weapons in the urban environment including:

- conducting operations in the presence of non-combatants and civilians
- neutralizing equipment and vehicles
- stopping moving targets for lethal kill
- reducing damage to facilities and buildings
- buying time/ evasion/ escape
- maintaining concealment/ covertness (when the available lethal alternatives provide a location signature)
- engagement escalation control
- neutralizing targets that cannot be engaged with explosives, such as a WMD facility.



An assessment of the programmatic needs for NLW was made as part of the study and is summarized above. In brief, "we've got the bookends"; i.e., at one end of the spectrum, an OSD NLW policy was approved in July 1996, and at the other end, numerous technologies, at varying levels of maturity, exist. The other aspects required to flesh out a comprehensive development and deployment program are beginning to emerge.

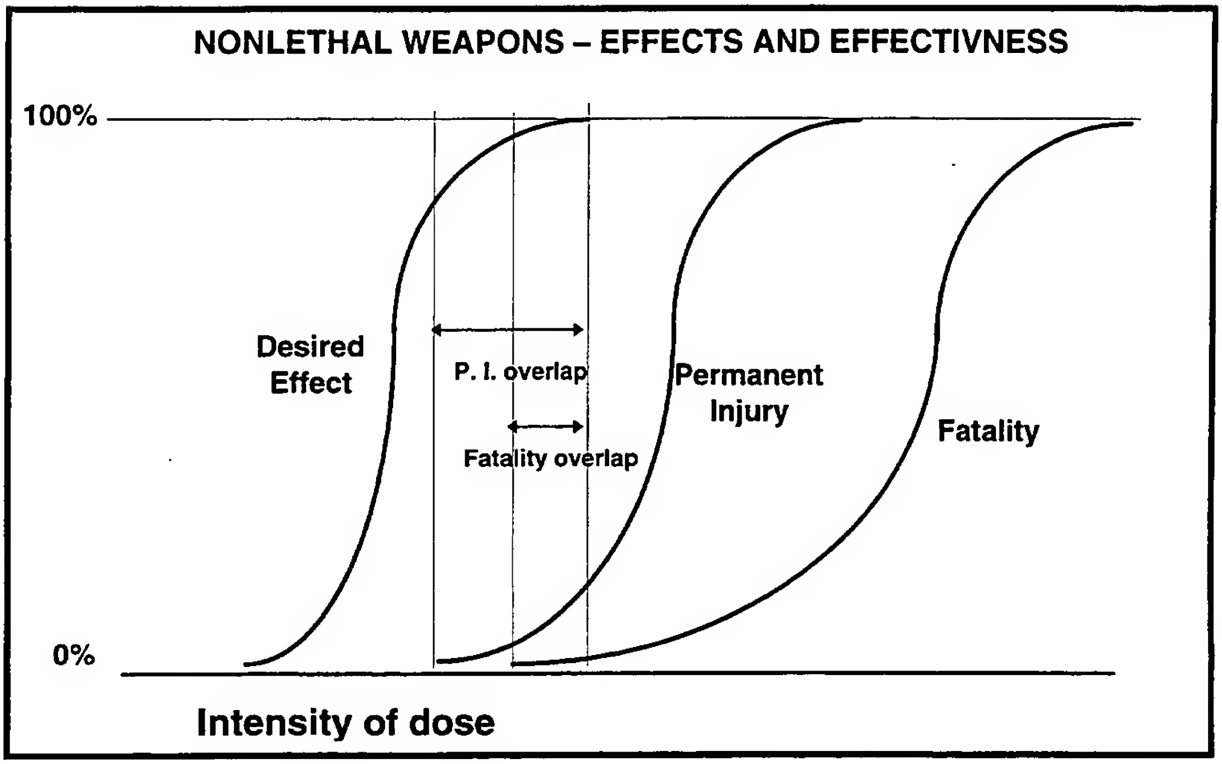
In order to drive future technology development in a more focused manner, a program in which the elements of operational experience, test and simulation are combined with a thorough understanding of NLW effects and effectiveness is needed. The objective is to transform the "technology push" of NLW to date into an iterative process with a much stronger "operational needs" dimension. The snapshot status of these elements is summarized above and in the comments below.

Integrated Program. With the March 1996 assignment of the Marine Corps as Executive Agent (EA) for the NLW Program, the fragmented pieces of NLW development and acquisition are starting to be pulled together under a proposed structure of an Integrated Product Team organized around a Joint Concepts Requirements Group and Joint Acquisition Group and administered by a Joint NLW Directorate. Multi-year funding

profiles have been drafted and include currently unfunded requests for acceleration of technologies into the forces.

Experience Base. Additional operational experience is growing with operations in Bosnia. In a more structured approach, dedicated exercises evaluating NLW use in Marine and joint Marine/Army LOEs are underway. In the context of more complex operational environments, NLW test and evaluation are parts of the Marines' Sea Dragon ACTD and the joint Military Operations in Urban Terrain (MOUT) ACTD. Questions being addressed across this spectrum of field experimentation and test include: an assessment of platforms for NLW deployment; new tactics, techniques and procedures; roles and effectiveness for emerging NLW technologies; optimum mix of platforms and technologies; calibration/correlation of operational simulations; expansion of NLW use to larger area/mid-intensity conflicts.

Simulation. Modeling and gaming are key elements to complement the limited insights provided by field test and actual conflicts. Probably the major missing element of this aspect of the program is consensus on a set of Measure of Effectiveness (MOEs) that would help focus the development of both operational and technology requirements. The inclusion of NLW options in gaming exercises should also become more common.



Effects and Effectiveness. Underpinning the model development is the need for the basic data that characterizes a given NLW technology with respect to its effects on targets, both intended and unintended, and the trade space of range, coverage, and persistency of effects. The assessment of vulnerabilities and countermeasures to any option currently available or planned for deployment is also essential and to our knowledge is not yet being systematically pursued. A set of new capabilities is needed to measure bio-effects more accurately, to assess vulnerability and countermeasures and to develop appropriate simulation tools. Until all these elements are developed and integrated into a robust program, technology development is likely to remain ad hoc and insertion into the forces slower than desired.

One of the general principals for nonlethal weapons contained in DoD directive 3000.3, dated July 9, 1996, recognized the risk of NLW use. No NLW is required to have zero probability of fatalities or permanent injury, but any NLW option should seek to strike a balance between low probability of fatalities, permanent injury or collateral damage and high probability of desired effects. The above figure illustrates the intent of this principle.

COMPENDIUM OF NONLETHAL WEAPONS

Mechanical
Kinetic energy (projectiles, fluids)
Binding agents (sticky foam, entanglements, adhesives
Conductive devices (particles, ribbons)
Obscurants (fogs, smoke)
Sabotage Devices (filters, coltrops, coatings)

Electromagnetic
High Energy Particles
X-Ray devices
UV lasers
Visible light (lasers, beams omni directional sources)
Microwave (Deception Antipersonnel, HPM)
Radio Wave, EMP
Directed Current (stun, cattle prod, Vehicle support)

Chemical
Material modifiers
(viscosity, corrosive, caustic, embrittling, depolymerization, combustion, soil / cloud, destabilizes

Anti-biological
(calmatives, gastrointestinal, neuropharmacological, irritants, odors, livestock, agents, herbicides

Acoustic
Subsonic, Sonic, Ultrasonic
(acoustic projection / jamming, ultasound, flash bang)

Biological
Organic biocides

Consuming organisms

Pathogens

Supporting Technologies
Delivery Vehicles (robot, UAV)

Sensors (shock, location, WMD, intrusion)

Miscellaneous (personal ID, translators

Several sources for descriptions and assessments of NLW technologies exist. The most complete is the "Survey of Limited Effects Weapons, Munitions, and Devices" prepared by Battelle Columbus for USSOCOM and DARPA (2nd edition, December 1995). Based on the taxonomy from a recent JAYCOR study for OASD(SO/LIC) entitled "Mission Applications for Non-Lethal Weapons" (July, 1996), NLW technologies can be grouped as shown above. With respect to maturity, the technologies fall into roughly three categories:

1) Off-the-shelf. Examples include irritants, KE devices such as "stun guns" and low-impact weapons, caltrops, barriers, and visible light sources.
2) Relatively near term. Included in this category are foams, entanglements, anti-traction fluids, and mines based on non-lethal obscurants, anti-biologicals, etc..
3) Longer term. Acoustic and most EM technologies fall in this group.

Those classed in the first group have had some limited operational deployment in military environments but build on a richer experience base in security or law enforcement applications. We are at relatively lower point on the operational "learning curve" for those technologies in the second group. Some are being introduced into Marine Corps and Army Limited Objective Experiments (LOEs) with further plans for employment in ACTDs. The third group is lagging even further behind in terms of operational concepts.

Almost all of the technologies suffer from an incomplete or nonexistent understanding of their biological effects. In other words, quantitative versions of the figure on page C-17 for each technology have not yet been fully developed.

Appendix D
Glossary

Glossary

AAV	Advanced Air Vehicle
AAV	Autonomous Air Vehicle
ACD	Advanced Concept Demonstration
ACTD	Advanced Concept Technology Demonstration
AFATDS	Advanced Field Artillery Tactical Data System
AFMSS	Air Force Mission Support System
AJ	Anti-Jam
AOR	Area of Responsibility
APOD	Air Point of Debarkation
ASAS	All Source Analysis System
ASD(C^3I)	Assistant Secretary of Defense (Command, Control, Communications and Intelligence)
ASW	Anti-Submarine Warfare
ATACM	Army Tactical Missile System
ATD	Advanced Technology Demonstration
ATR	Automatic Target Recognition
AWACS	Airborne Warning and Control System
BADD	Battlefield Awareness Data Dissemination
BAT	Brilliant Anti-Tank
BDA	Battle Damage Assessment
BDE	Brigade
BM/C^2	Battle Management/ Command and Control
BMIC	Battlefield Integration and Management Cell
BW	Biological Warfare
C^2W	Command and Control Warfare
C^3	Command, Control, and Communications
C^4ISR	Command, Control, Communications, Computers, and Intelligence Surveillance Reconnaissance
CALCM	Conventional Air Launched Cruise Missile
CEC	Cooperative Engagement Capability
CFF	Call For Fire
COE	Common Operating Environment
CONOPS	Concept of Operations
CONUS	Continental United States
CINC	Commander in Chief
CJCS	Chairman, Joint Chiefs of Staff
CMC	Commandant, Marine Corps
CSS	Combat Service Support
CW	Chemical Warfare
DARPA	Defense Advanced Research Projects Agency
DCC	Distributed Combat Cell
DDR&E	Deputy Director for Research and Engineering

DF	Direction Finding
DoD	Department of Defense
DRB	Division-Ready Brigade
DSB	Defense Science Board
DTUPC	Design-to-Unit-Production-Cost
EA	Executive Agent
EFP	Explosively-Formed-Penetrator
ELINT	Electronics Intelligence
EO	Electro-Optical
FOFAC	Forward Observer, Forward Air Controller
FOGM	Fiber Optic Guided Missile
FOPEN	Foliage Penetration
FRV	Future Reconnaissance Vehicle
FY	Fiscal Year
GLONASS	(Soviet) Global Navigation Satellite System
GPS	Global Positioning System
HAE	High Altitude Endurance
HUMINT	Human Intelligence
IADS	Integrated Air Defense Systems
IDA	Institute for Defense Analysis
INS	Inertial Navigation System
IPT	Integrated Product Team
IR	Infrared
IR&D	Independent Research and Development
IW	Information Warfare
JCS	Joint Chiefs of Staff
JFACC	Joint Force Air Component Commander
JPODS	Joint Precision Offset Delivery System
JSTARS	Joint Systems Target Acquisition Radar System
JTF	Joint Task Force
LADAR	Laser Radar
LESTFOR	Leading Edge Strike Force
LOCAAS	Low Cost Autonomous Attack System
LOS	Line-of-Sight
LPI	Low Probability of Intercept
LSQ/A	Landing Ship Quay/Causeway
MAE	Medium Altitude Endurance
MER	Munition Ejector Rack
MMICS	Monolithic Microwave Integrated Circuits
MIRV	Multiple Independent Re-entry Vehicle

ModSAF	Modified Synthetic Automated Forces
MOE	Measure of Effectiveness
MOF	Map of the Future
MOUT	Military Operation in Urban Terrain
MTI	Moving Target Identification
NCA	National Command Authority
NLT	No Later Than
NLW	Non-Lethal Weapons
OSD	Office of the Secretary of Defense
OUSD(A&T)	Office of the Under Secretary of Defense (Acquisition and Technology)
PDA	Personal Data Assistant
POM	Program Objective Memorandum
PST	Precision Strike Team
RF	Radio Frequency
RISTA	Reconnaissance, Intelligence, Surveillance, and Target Acquisition
SAR	Synthetic Aperture Radar
SATCOM	Satellite Communications
SEAD	Suppression of Enemy Air Defense
SECDEF	Secretary of Defense
SEI	Software Engineering Institute
SIGINT	Signals Intelligence
SKEET	Anti-armor submunition
SOCOM	Southern Command
SOF	Special Operations Force
SPOD	Sea Point of Debarkation
SWA	South West Asia
TBMCS	Theater Battle Management Core System
TII	Tactical Information Infrastructure
TMD	Tactical Munition Dispenser
TRAC	TRADOC Analysis Center
TRADOC	Training and Doctrine Command
UAV	Unmanned Aerial Vehicle
UGS	Unattended Ground Sensors
UHF	Ultra High Frequency
USACOM	United States Americas Command
USD(A&T)	Under Secretary of Defense (Acquisition and Technology)
UUV	Underwater Unmanned Vehicle
VCJCS	Vice Chairman, Joint Chiefs of Staff
VLO	Very Low Observable
VLS	Vertical Launch System
VTOL	Vertical Takeoff and Landing

WMD	Weapons of Mass Destruction
WSO	Weapon System Officer